



Forthcoming Drell-Yan experiment at COMPASS



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For the COMPASS collaboration
12.05.2011



Outline



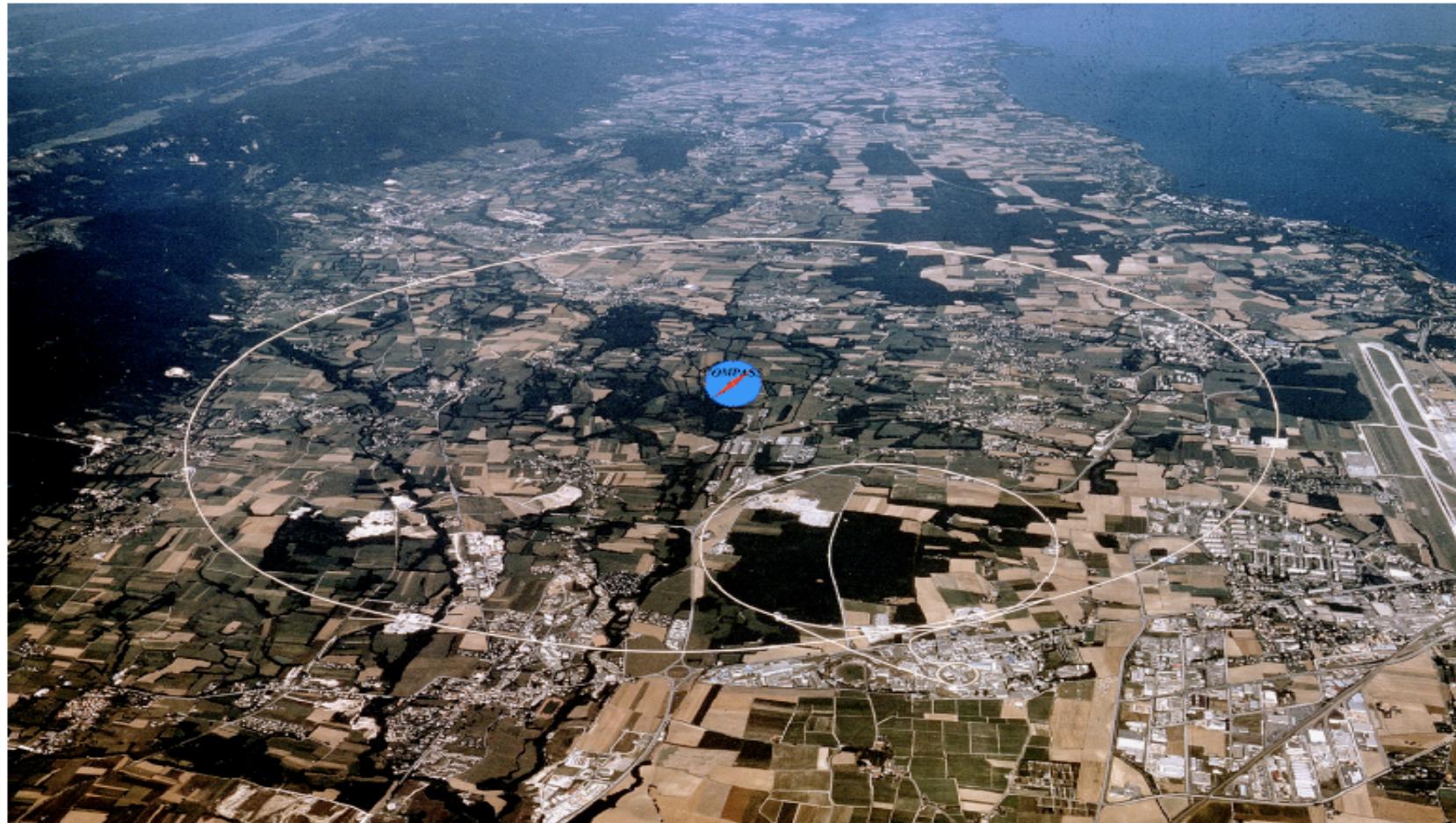
- COMPASS I → COMPASS-II
- Drell-Yan, polarised case
- Transversity & TMDs (single transversally polarised DY, this workshop – George Sterman, Gunar, Mauro,....):
 - Proton description at LO
 - Proton spin → quark orbital angular momentum
 - TMDs factorisation and universality – crucial test of modern QCD
- Unpolarised pion Drell-Yan (Paul Reimer and Jen-Chieh Peng)
- TMDs study – choice of kinematic domain
- Polarised DY@COMPASS
 - Set-up
 - Kinematics & Projections
 - Beam test
 - Upgrades & Timelines
- Some conclusions



COMPASS facility at CERN (SPS)

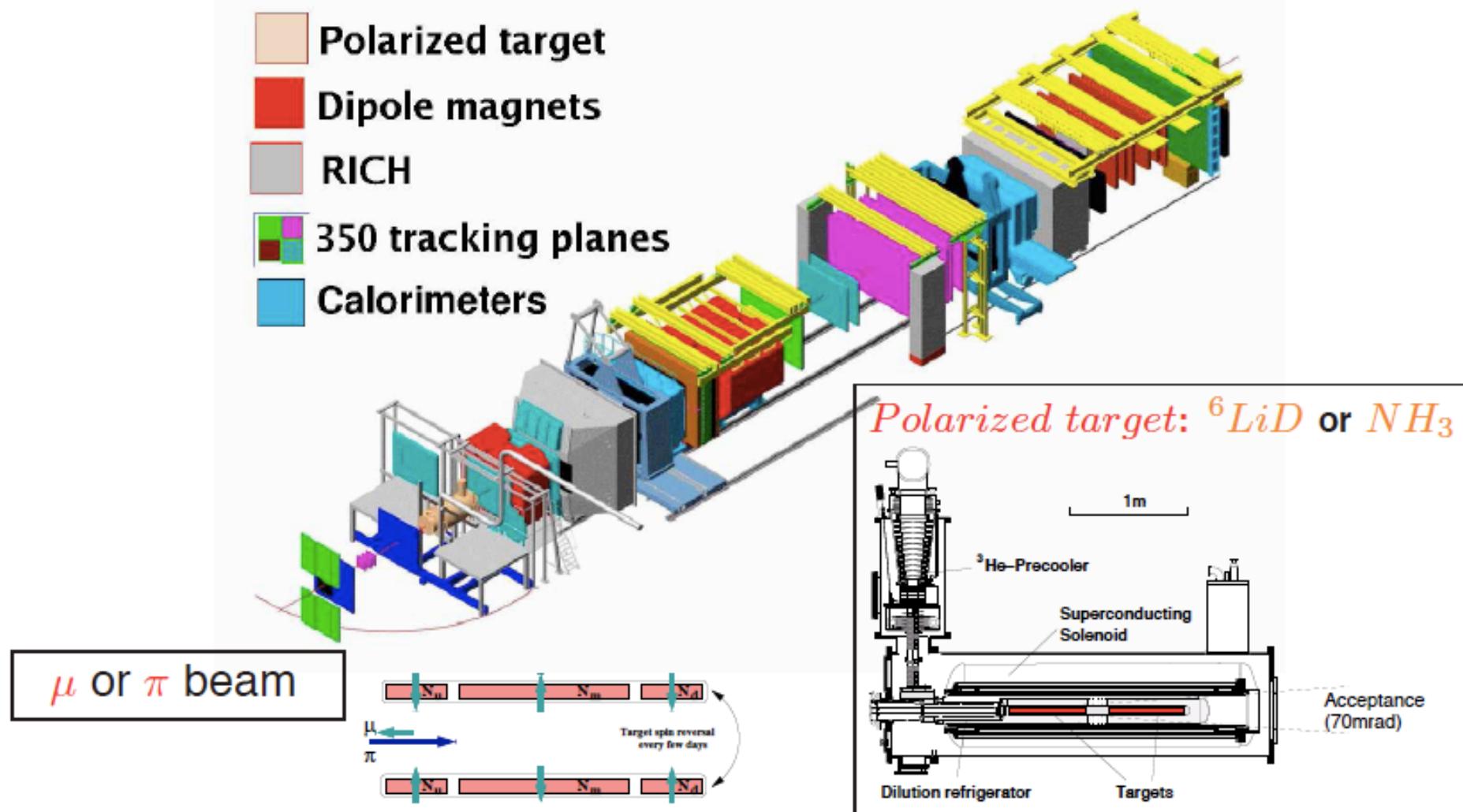


COmmon Muon Proton Apparatus for Structure and Spectroscopy





COMPASS facility at CERN





COMPASS-II (New Physics) a piece of history



- COMPASS is very sophisticated, universal and flexible facility → Physics beyond SIDIS and hadron spectroscopy is possible:
 - Unique COMPASS Polarised Target
 - Both hadron and lepton beams
 - Easy-accessible spectrometer components
- All that together has generated new physics proposals with COMPASS – DVCS(GPDs) and polarised DY:
 - For the first time these ideas (GPD and DY) were reported at the Villars SPSC meeting in September 2004
 - Since then (DY part) 3 International Workshops (Torino, Dubna, CERN), > 40 COMPASS DY subgroup meetings, 3 Beam Tests, > 20 presentations at the international Conferences....
- The COMPASS-II proposal was submitted to the CERN SPSC on May 17th 2010
- Approved by the CERN research board on December 1st 2010, 1 year for Drell-Yan and 2 years for GPDs in the time interval between two LHC shutdowns.
- April 7th – the Collaboration took a decision to run first the DY program and then DVCS (GPDs) program – we will start in 2013 (beam test) and in 2014 we will have a full year of DY data taking.

COMPASS-II: a Facility to study QCD (SPSC,CERN)



**COMMON
MUON and
PROTON
APPARATUS for
STRUCTURE and
SPECTROSCOPY**

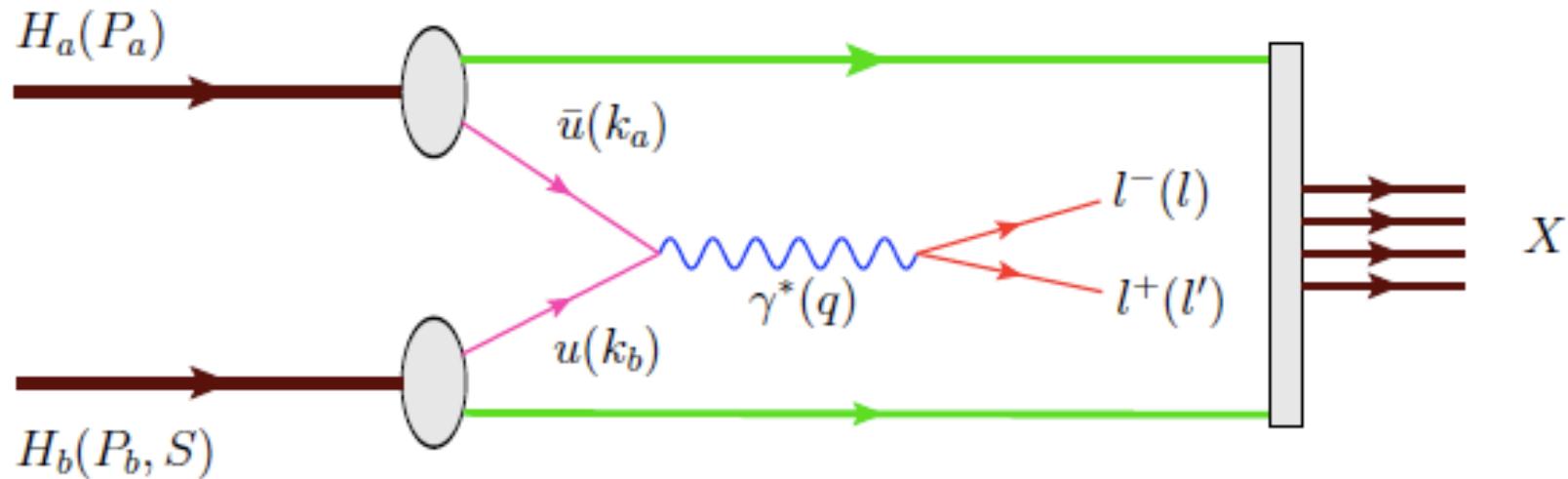
Long Term Plans for at least 5 years (starting in 2012)

- ✓ Primakoff with π , K beam → Test of Chiral Perturb. theory
- ✓ DVCS & DVMP with μ beams → Transv. Spatial Distrib. with GPDs
- ✓ SIDIS (with GPD prog.) → Strange PDF and Transv. Mom. dep. PDFs
- ✓ Drell-Yan with π beams → Transverse Momentum dependent PDFs

O. Denisov (INFN Torino) - DY, J. Friedrich (TU Munich) - Primakoff, N. d'Hose (CEA Saclay) - GPD
for the COMPASS Collaboration



Drell-Yan Kinematics



$$\begin{aligned} s &= P_{a(b)}^2, \\ x_{a(b)} &= q^2 / (2P_{a(b)} \cdot q), \\ x_F &= x_a - x_b, \\ M_{\mu\mu}^2 &= Q^2 = q^2 = s x_a x_b, \\ \mathbf{k}_{T a(b)} & \\ \mathbf{q}_T &= \mathbf{P}_T = \mathbf{k}_{T a} + \mathbf{k}_{T b} \end{aligned}$$

the momentum of the beam (target) hadron,
the total centre-of-mass energy squared,
the momentum fraction carried by a parton from $H_{a(b)}$,
the Feynman variable,
the invariant mass squared of the dimuon,
the transverse component of the quark momentum,
the transverse component of the momentum of the virtual photon.



Drell-Yan cross-section – general (full) angular distribution



2008: [S. Arnold, \(Ruhr U., Bochum\)](#) , [A. Metz, \(Temple U.\)](#) , [M. Schlegel, \(Jefferson Lab\)](#)
Phys.Rev.D79:034005,2009, e-Print: [arXiv:0809.2262](#)

$$\begin{aligned} \frac{d\sigma}{d^4 q d\Omega} = & \frac{\alpha_{em}^2}{F q^2} \times \\ & \left\{ \left((1 + \cos^2 \theta) F_{UU}^1 + (1 - \cos^2 \theta) F_{UU}^2 + \sin 2\theta \cos \phi F_{UU}^{\cos \phi} + \sin^2 \theta \cos 2\phi F_{UU}^{\cos 2\phi} \right) \right. \\ & + S_{aL} \left(\sin 2\theta \sin \phi F_{LU}^{\sin \phi} + \sin^2 \theta \sin 2\phi F_{LU}^{\sin 2\phi} \right) \\ & + S_{bL} \left(\sin 2\theta \sin \phi F_{UL}^{\sin \phi} + \sin^2 \theta \sin 2\phi F_{UL}^{\sin 2\phi} \right) \\ & + |\vec{S}_{aT}| \left[\sin \phi_a \left((1 + \cos^2 \theta) F_{TU}^1 + (1 - \cos^2 \theta) F_{TU}^2 + \sin 2\theta \cos \phi F_{TU}^{\cos \phi} + \sin^2 \theta \cos 2\phi F_{TU}^{\cos 2\phi} \right) \right. \\ & \quad \left. + \cos \phi_a \left(\sin 2\theta \sin \phi F_{TU}^{\sin \phi} + \sin^2 \theta \sin 2\phi F_{TU}^{\sin 2\phi} \right) \right] \\ & + |\vec{S}_{bT}| \left[\sin \phi_b \left((1 + \cos^2 \theta) F_{UT}^1 + (1 - \cos^2 \theta) F_{UT}^2 + \sin 2\theta \cos \phi F_{UT}^{\cos \phi} + \sin^2 \theta \cos 2\phi F_{UT}^{\cos 2\phi} \right) \right. \\ & \quad \left. + \cos \phi_b \left(\sin 2\theta \sin \phi F_{UT}^{\sin \phi} + \sin^2 \theta \sin 2\phi F_{UT}^{\sin 2\phi} \right) \right] \\ & + S_{aL} S_{bL} \left((1 + \cos^2 \theta) F_{LL}^1 + (1 - \cos^2 \theta) F_{LL}^2 + \sin 2\theta \cos \phi F_{LL}^{\cos \phi} + \sin^2 \theta \cos 2\phi F_{LL}^{\cos 2\phi} \right) \end{aligned}$$



Leading Order PDFs



At leading order, 3 PDFs are needed to describe the structure of the nucleon in the collinear approximation.

But if one takes into account also the quarks intrinsic transverse momentum k_T , 8 PDFs are needed:

NUCLEON		
unpolarized	longitudinally pol.	transversely pol.
QUARK		
f_1 number density		f_{1T}^\perp Sivers
	g_{1L} helicity	g_{1T}
h_1 Boer-Mulders		h_1 transversity
	h_{1L}^\perp	h_{1T}^\perp pretzelosity



Single-polarised DY cross-section: Leading order QCD parton model



At LO the general expression of the DY cross-section simplifies to (Aram Kotzinian) :

$$\begin{aligned} \frac{d\sigma^{LO}}{d^4q d\Omega} = & \frac{\alpha_{em}^2}{F q^2} \hat{\sigma}_U^{LO} \left\{ \left(1 + D_{[\sin^2 \theta]}^{LO} A_U^{\cos 2\phi} \cos 2\phi \right) \right. \\ & + S_L D_{[\sin^2 \theta]}^{LO} A_L^{\sin 2\phi} \sin 2\phi \\ & + |\vec{S}_T| \left[A_T^{\sin \phi_S} \sin \phi_S + D_{[\sin^2 \theta]}^{LO} \left(A_T^{\sin(2\phi+\phi_S)} \sin(2\phi+\phi_S) \right. \right. \\ & \left. \left. + A_T^{\sin(2\phi-\phi_S)} \sin(2\phi-\phi_S) \right) \right] \right\}, \end{aligned}$$

Thus the measurement of 4 asymmetries (modulations in the DY cross-section):

- $A_U^{\cos 2\phi}$ gives access to the Boer-Mulders functions of the incoming hadrons,
- $A_T^{\sin \phi_S}$ – to the Sivers function of the target nucleon,
- $A_T^{\sin(2\phi+\phi_S)}$ – to the Boer-Mulders functions of the beam hadron and to h_{1T}^\perp , the pretzelosity function of the target nucleon,
- $A_T^{\sin(2\phi-\phi_S)}$ – to the Boer-Mulders functions of the beam hadron and h_1 , the transversity function of the target nucleon.



TMDs universality SIDIS ↔ DY



The time-reversal odd character of the Sivers and Boer-Mulders PDFs lead to the prediction of a sign change when accessed from SIDIS or from Drell-Yan processes:

↪ Check the predictions:

$$f_{1T}^\perp(DY) = -f_{1T}^\perp(SIDIS)$$

$$h_1^\perp(DY) = -h_1^\perp(SIDIS)$$

Its experimental confirmation is considered a crucial test of non-perturbative QCD.

Universality test includes not only the sing-reversal character of the TMDs but also the comparison of the amplitude as well as the shape of the corresponding TMDs



Sivers, Boer-Mulders functions SIDIS \leftrightarrow DY

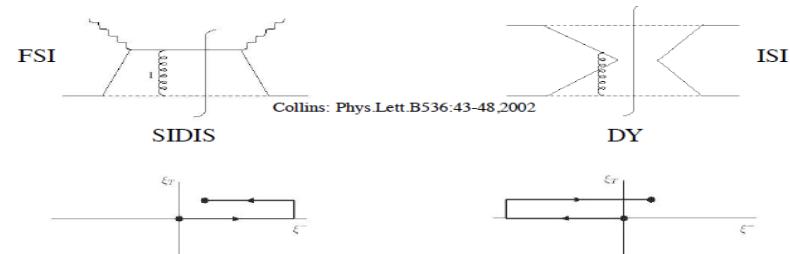
QCD

$$\sigma_h \approx \sigma_p \times \text{PDF}$$

QCD factorization, valid for hard processes only (Q , q_T are large)

Cross-sections are gauge-invariant objects, to provide the gauge invariance of the PDFs the gauge-link was introduced (intrinsic feature of PDF). The presence of gauge-link provides the possibility of existence of non-zero T-odd TMD PDFs

Direction of the gauge-link of the k_T dependent PDF is process-dependent (gauge-link is resummation of all collinear soft gluons) and it changes to the opposite in SIDIS wrt DY



Sivers and Boer-Mulders functions are T-odd, and to provide the time-invariance they change the sign in SIDIS wrt DY due to the opposite direction of the gauge-link

$$f_{1T}^\perp(x, \mathbf{k}_T) \Big|_{\text{SIDIS}} = -f_{1T}^\perp(x, \mathbf{k}_T) \Big|_{\text{DY}}$$

$$h_1^\perp(x, \mathbf{k}_T) \Big|_{\text{SIDIS}} = -h_1^\perp(x, \mathbf{k}_T) \Big|_{\text{DY}}$$

J.C. Collins, Phys. Lett. B536 (2002) 43

J. Collins, talk at LIGHT CONE 2008



SIDIS↔DY – QCD test



Andreas Metz (Trento-TMD'2010):

Sign reversal of the Sivers function

- Prediction based on operator definition (Collins, 2002)

$$f_{1T}^\perp|_{DY} = - f_{1T}^\perp|_{DIS}$$

- What if sign reversal of f_{1T}^\perp is not confirmed by experiment?
 - Would not imply that QCD is wrong
 - Would imply that SSAs not understood in QCD
 - Problem with TMD-factorization
 - Problem with resummation of large logarithms
 - Resummation relevant if more than one scale present
 - CSS resummation in Drell-Yan (Collins, Soper, Sterman, 1985); resum logarithms of the type

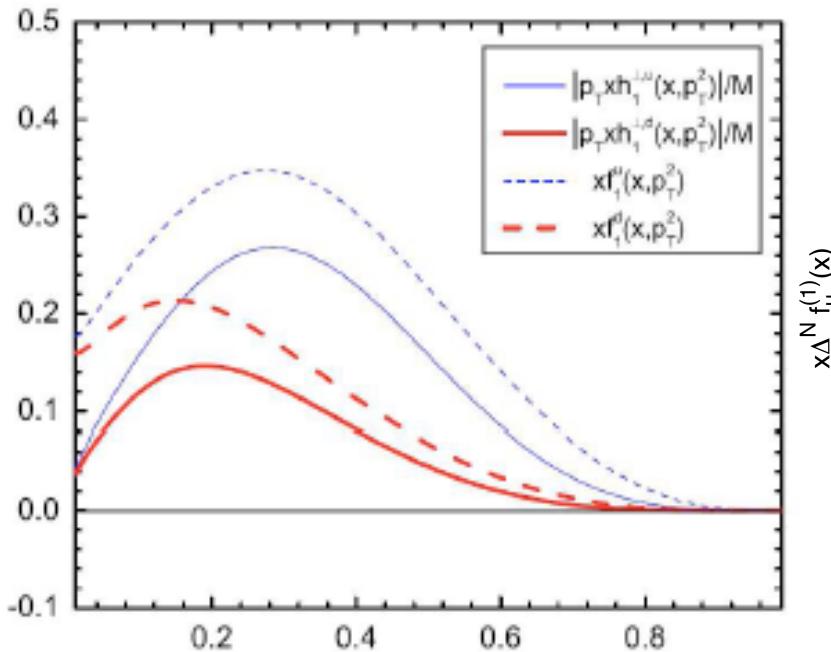
$$\alpha_s^k \ln^{2k} \frac{\vec{Q}_T^2}{Q^2}$$

→ Has also implications for Fermilab and LHC physics

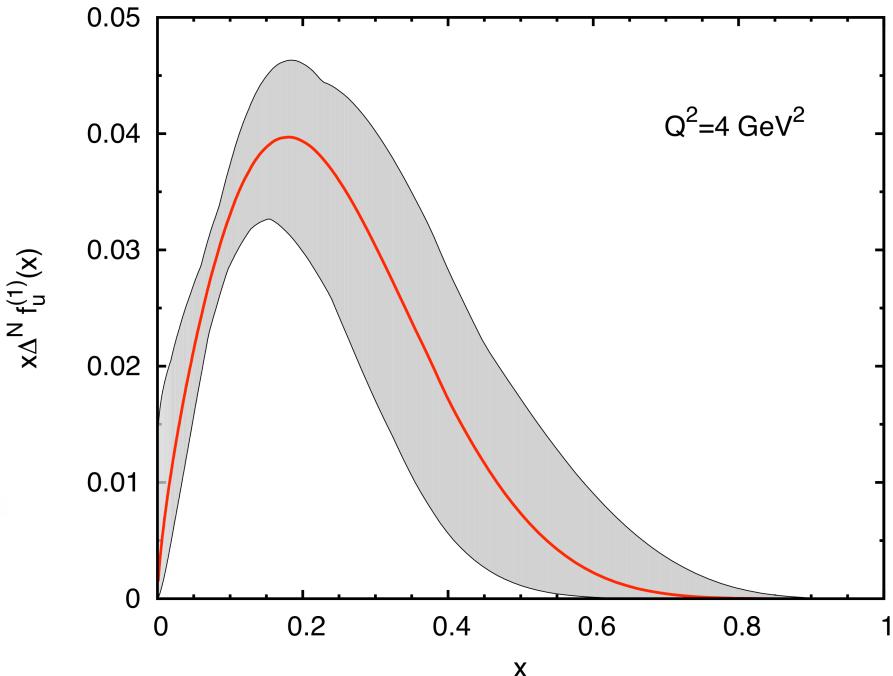


Some indications for the future Drell-Yan experiments

1. TMD PDFs – ALL are sizable in the valence quark region



► Boer-Mulder function for u and d quarks
as extracted from $p + D$ data
from Zhang *et al* Phys. Rev. D77,0504011]



Sivers effect in Drell-Yan processes.
M. Anselmino, M. Boglione U. D'Alesio,
S. Melis, F. Murgia, A. Prokudin
Published in Phys.Rev.D79:054010, 2009

2. $\Lambda_{QCD} < p_T < Q$: - P_T should be small ($\sim 1 \text{ GeV}$), can be generated by intrinsic motion of quarks and/or by soft gluon emission. This is the region where TMD formalism applies.



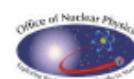
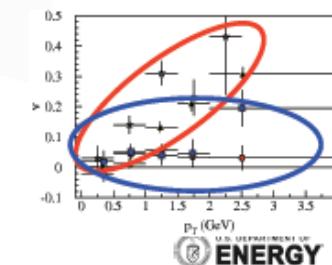
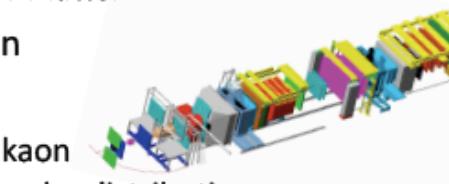
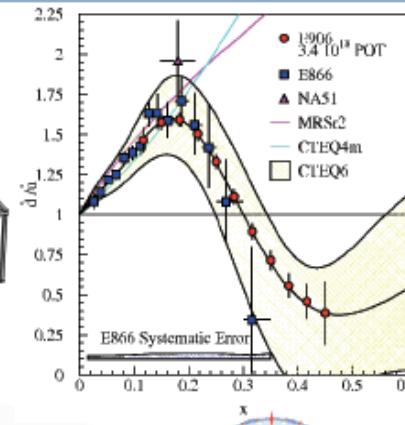
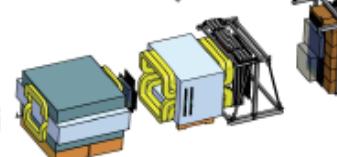
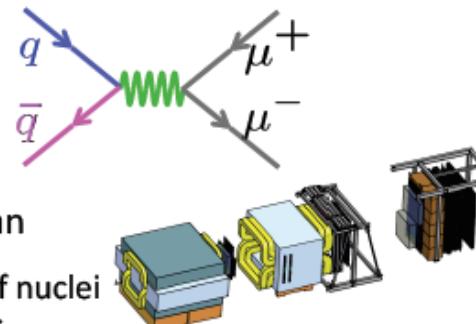
Unpolarised Drell-Yan → Paul Reimer seminar at Torino 13/04/2011



What can we learn with unpolarized Drell-Yan?

Paul E. Reimer
Physics Division
Argonne National Laboratory
13 April 2011

- **Proton induced Drell-Yan**
 - Sea of the proton and of nuclei
 - High- x valence distributions
 - Partonic energy loss in cold nuclear matter
- **Pion (and Kaon) induced Drell-Yan**
 - EMC effect
 - Valence structure of the pion and kaon
 - Transverse Structure & QCD via angular distributions
 - Sea of the pion?



This work is supported in part by the U.S. Department of Energy,
Office of Nuclear Physics, under Contract No. DE-AC02-06CH11357.

We need very much unpolarised DY data to run successful polarised DY experiment



Why Drell-Yan @ COMPASS



1. Large angular acceptance spectrometer
2. SPS M2 secondary beams with the intensity up to 10^8 particles per second
3. Transversely polarized solid state proton target with a large relaxation time and high polarization, when going to spin frozen mode;
4. a detection system designed to stand relatively high particle fluxes;
5. a Data Acquisition System (DAQ) that can handle large amounts of data at large trigger rates;
6. The dedicated muon trigger system

For the moment we consider two step DY program:

- The program with high intensity pion beam
- The program with Radio Frequency separated antiproton beam

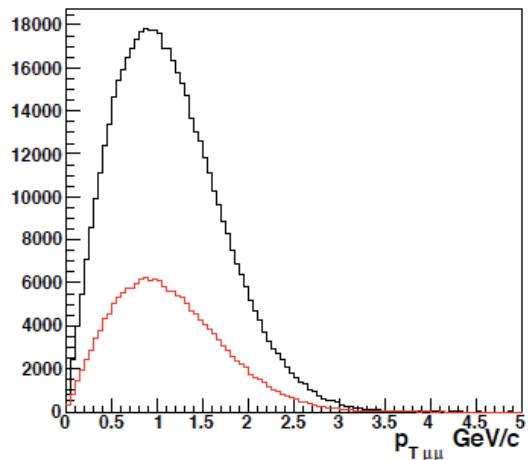


DY@COMPASS – kinematics - valence quark range

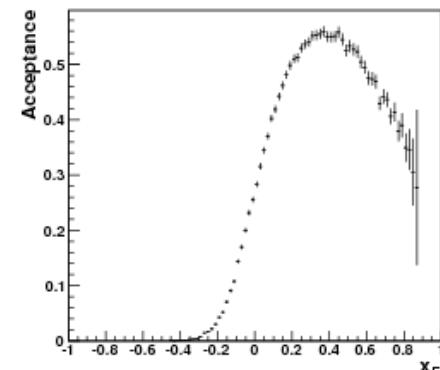
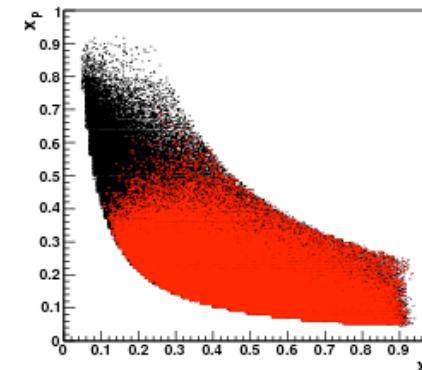
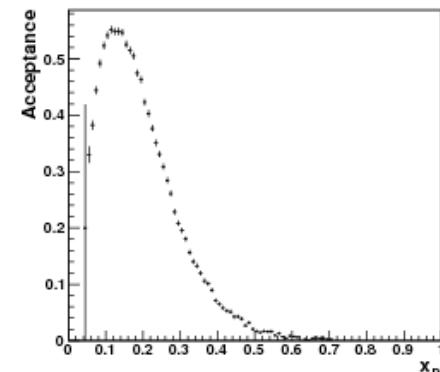
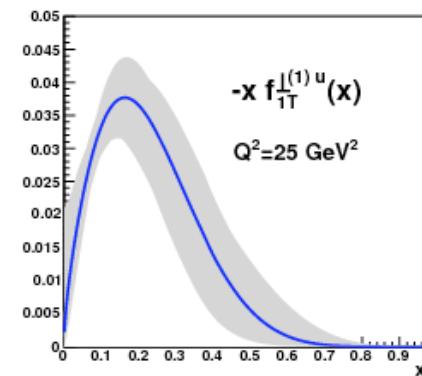
$\pi^- p \rightarrow \mu^- \mu^+ X$ (190 GeV pion beam)



- In our case ($\pi^- p \rightarrow \mu^- \mu^+ X$) contribution from valence quarks is dominant
- In COMPASS kinematics u-ubar dominance
- $\langle P_T \rangle \sim 1 \text{ GeV}$ – TMDs induced effects expected to be dominant with respect to the higher QCD corrections



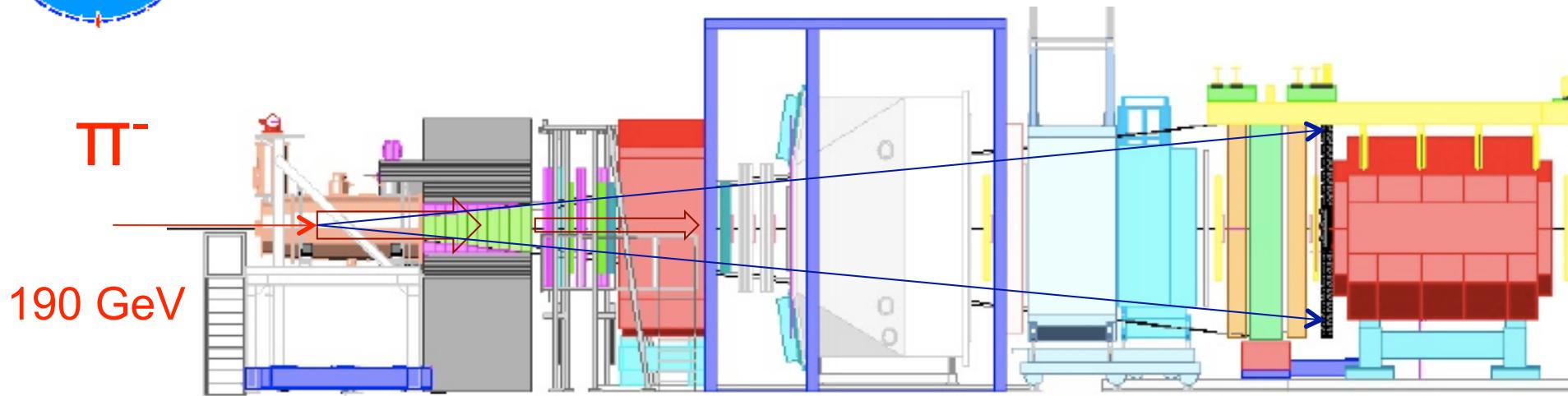
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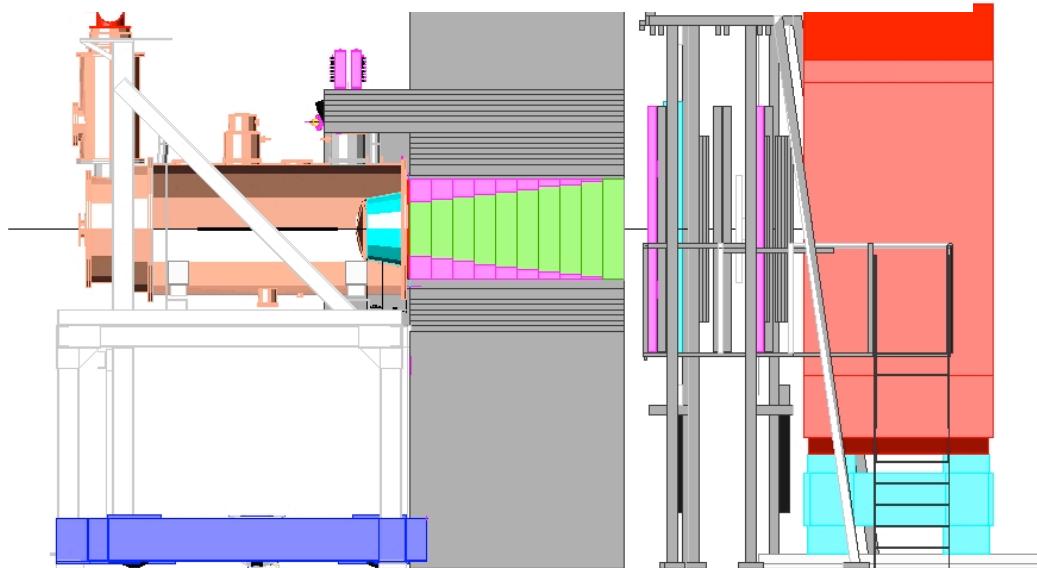


DY@COMPASS - set-up

$$\pi^- p \uparrow \rightarrow \mu^- \mu^+ X$$


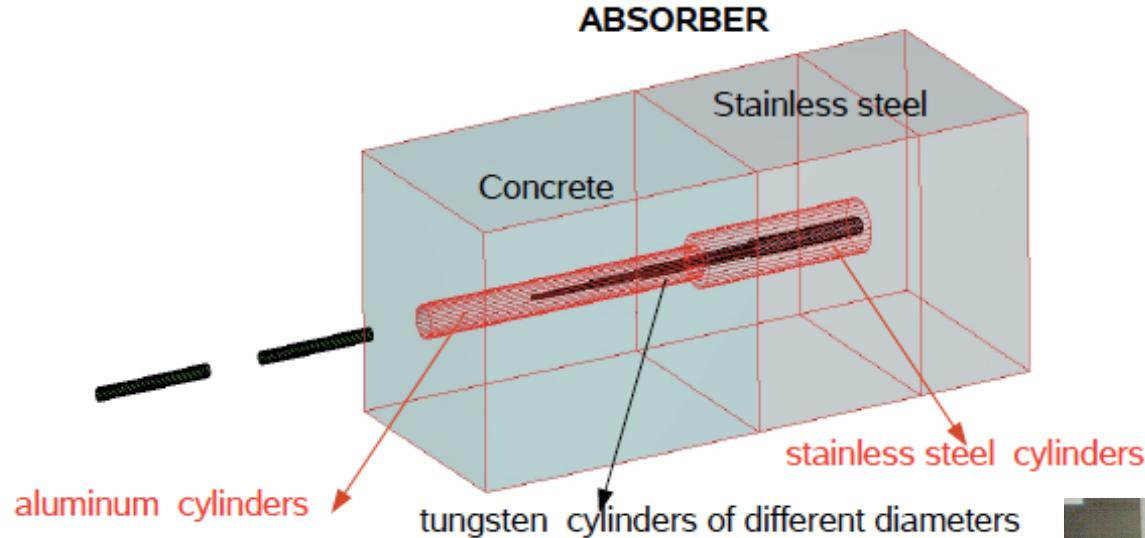
Key elements:

1. COMPASS PT
2. Tracking system (both LAS abs SAS) and beam telescope in front of PT
3. Muon trigger (in LAS is of particular importance - 60% of the DY acceptance)
4. RICH1, Calorimetry – also important to reduce the background (the hadron flux downstream of the hadron absorber ~ 10 higher than muon flux)





DY Feasibility@COMPASS: Beam Test 2009 – the most important in a row of three beam tests 2007-2009



12-05-2011

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DY Feasibility@COMPASS

Beam Test 2009 (with hadron absorber III)



Radiation in the experimental area,
detector occupancies and J/Psi
yield:

Everything as expected

12-05-2011

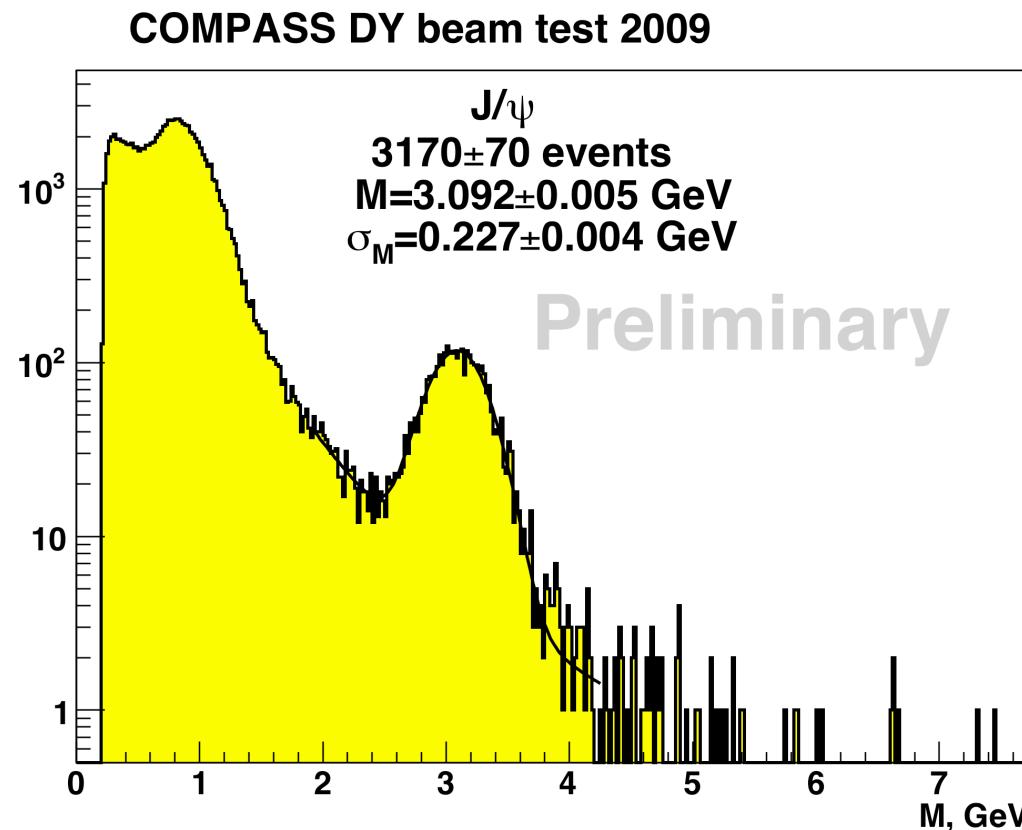
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DY@COMPASS - feasibility - Signal



- Expected according to the proposal J/Psi and Drell-Yan yields: 3600 ± 600 and 110 ± 22 (normalized to 2009 beam flux $\sim 3.7 \times 10^{11}$)
- Measured in 2009 beam test J/Psi yield is 3170 ± 70 , and DY yield is 84 ± 10





DY@COMPASS - feasibility – Kinematics I

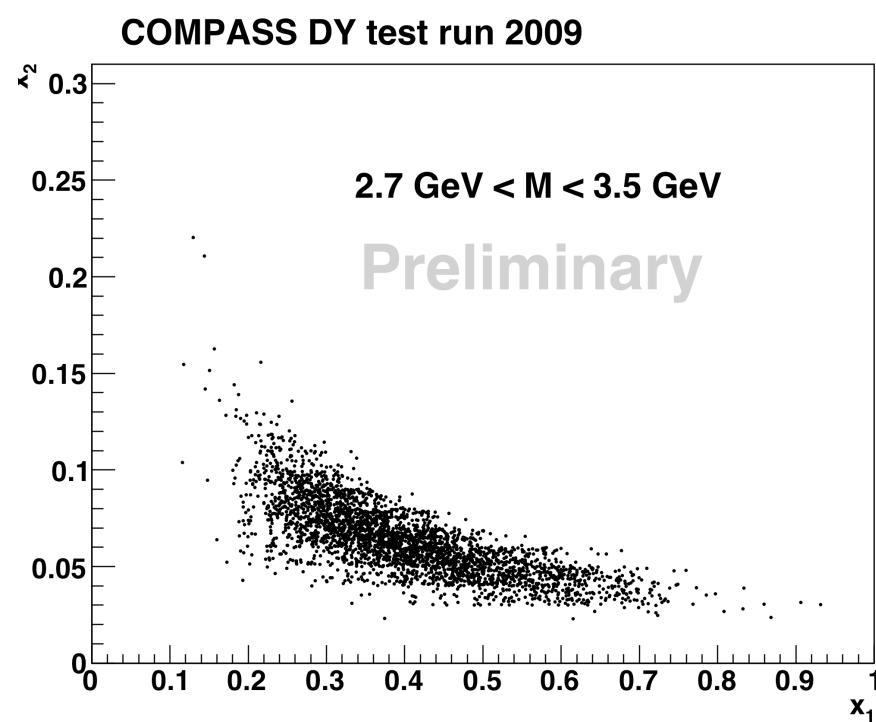
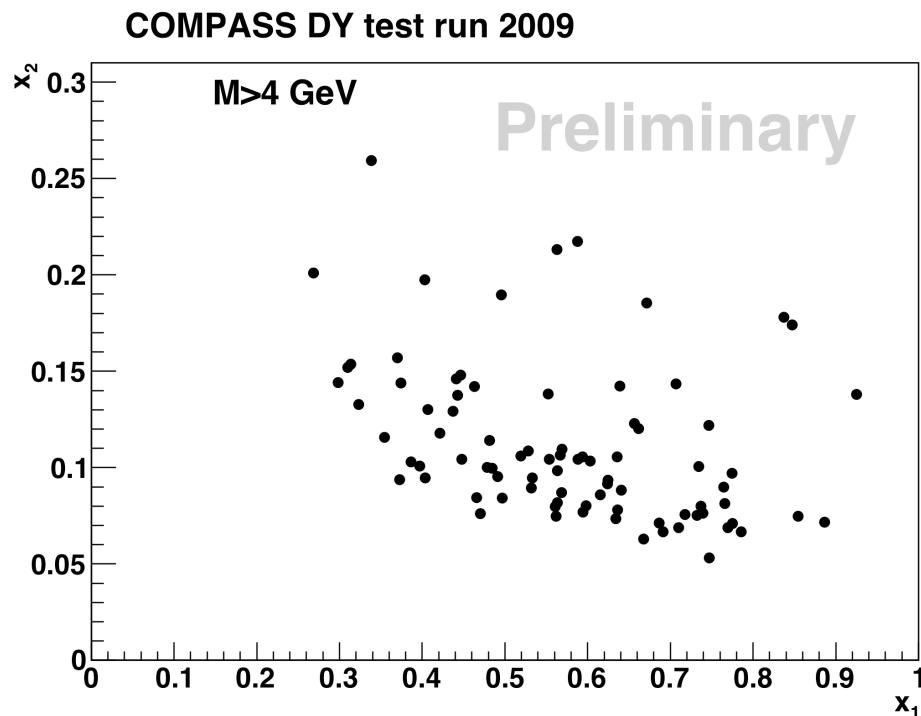


- Valence quark range for both J/Psi and DY

$$x_1 = \frac{Q^2}{P_1 q},$$

$$x_2 = \frac{Q^2}{P_2 q},$$

$$x_f = x_1 - x_2,$$

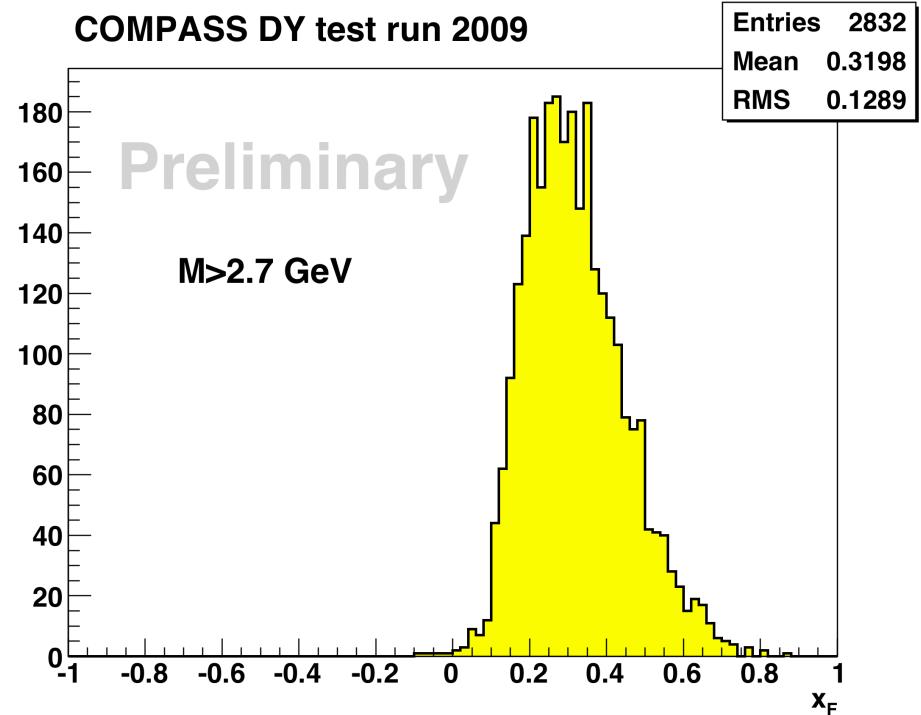
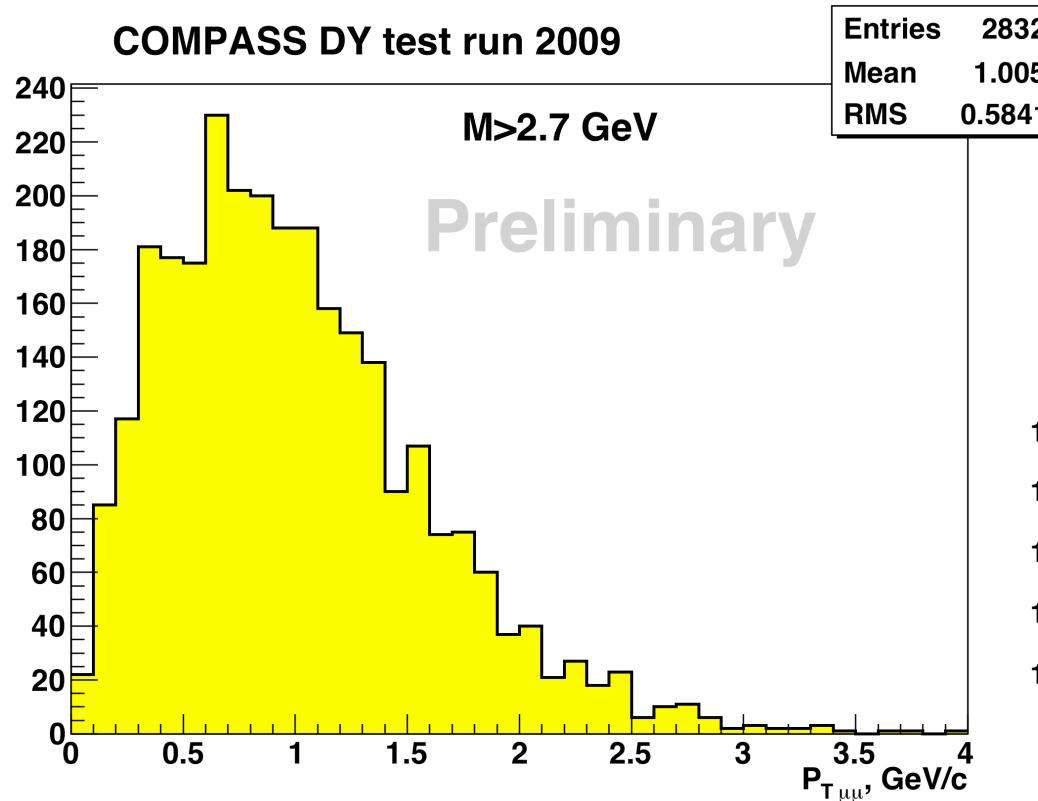




DY@COMPASS - feasibility – Kinematics II



q_T and x_F ranges





DY@COMPASS projections I

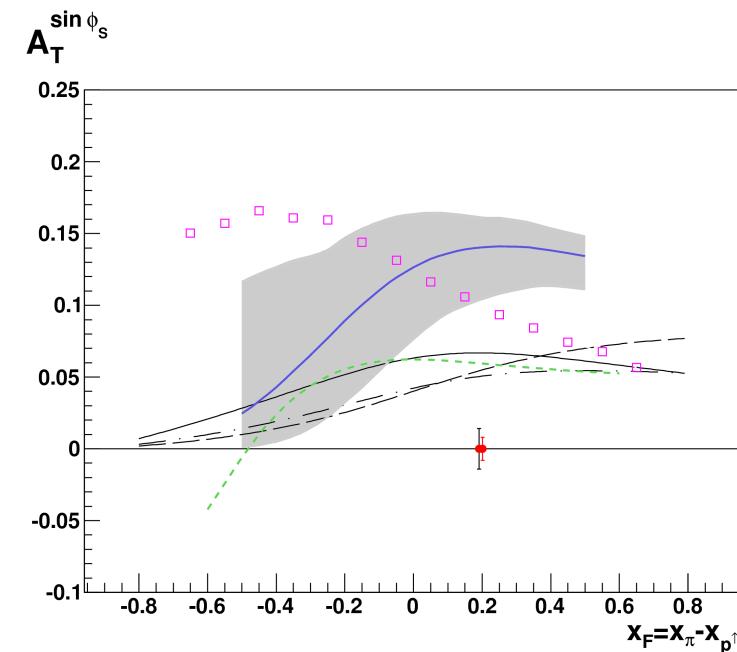


With a beam intensity $I_{beam} = 6 \times 10^7$ particles/second, a luminosity of $L = 1.7 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$ can be obtained.

→ Assuming 2 years of data-taking, one can collect > 200000 DY events in the region $4 < M_{\mu\mu} < 9. \text{ GeV}/c^2$.

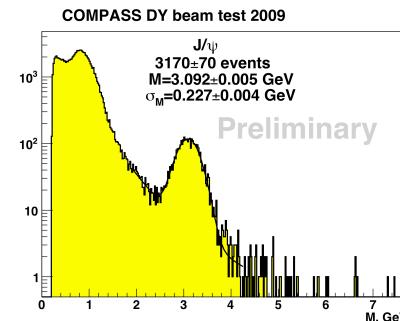
Predictions for the Sivers asymmetry in the COMPASS phase-space, for the mass region $4. < M < 9. \text{ GeV}/c^2$, compared to the expected statistical errors of the measurement:

- solid and dashed: Efremov et al,
PLB612(2005)233;
- dot-dashed: Collins et al,
PRD73(2006)014021;
- solid, dot-dashed: Anselmino et al,
PRD79(2009)054010;
- boxes: Bianconi et al, PRD73(2006)114002;
- short-dashed: Bacchetta et al,
PRD78(2008)074010.

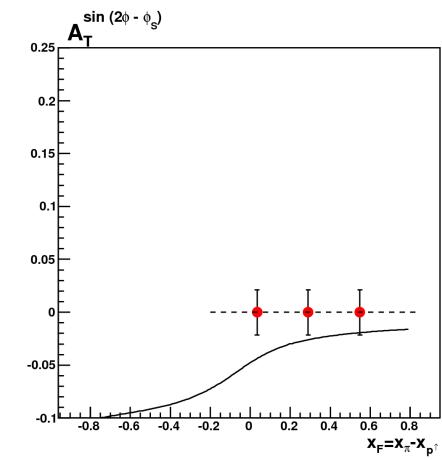
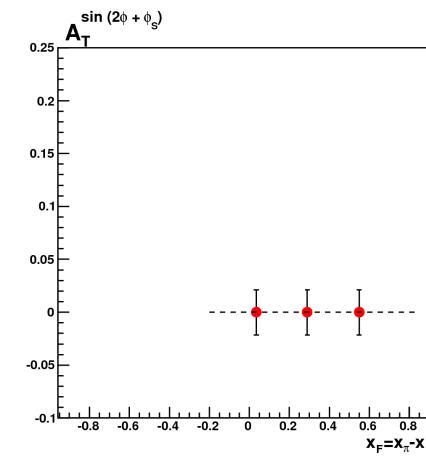
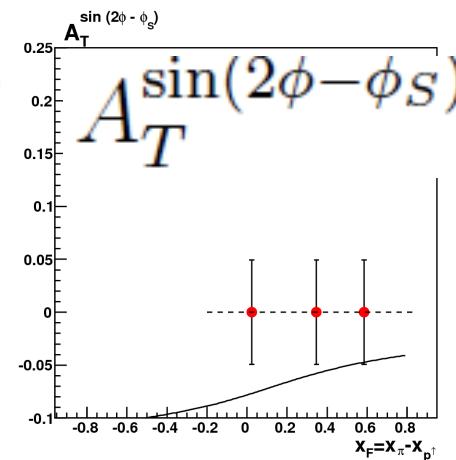
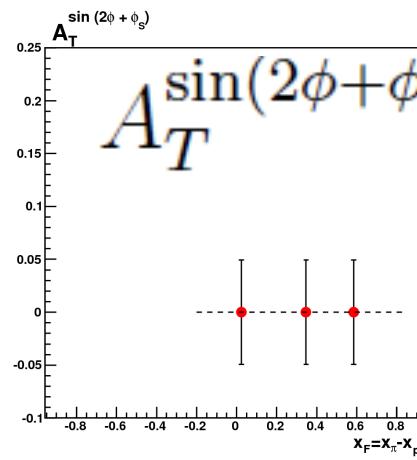
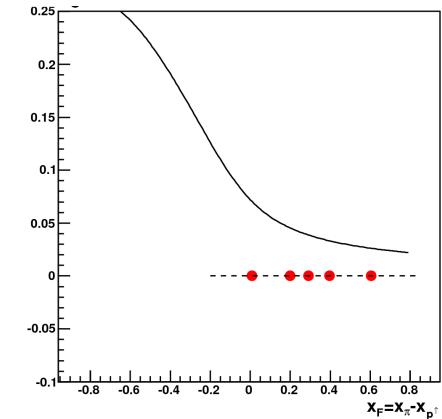
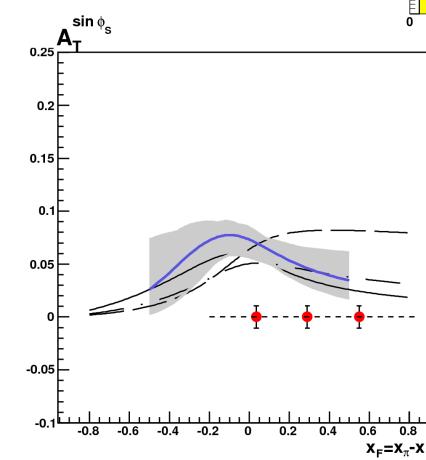
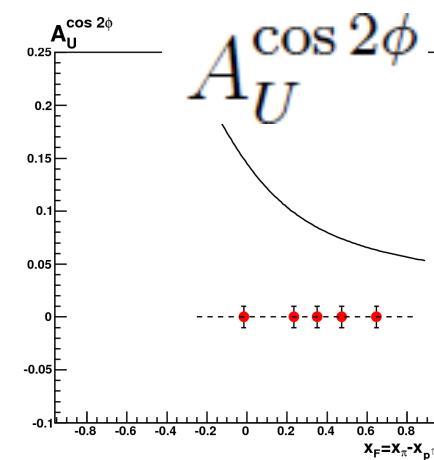
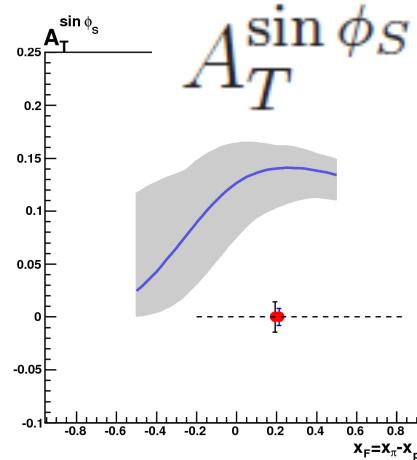




DY@COMPASS projections



IFN
Istituto Nazionale
di Fisica Nucleare
Sezione di Torino



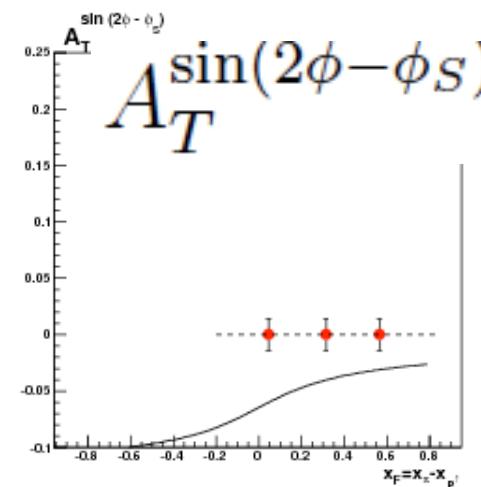
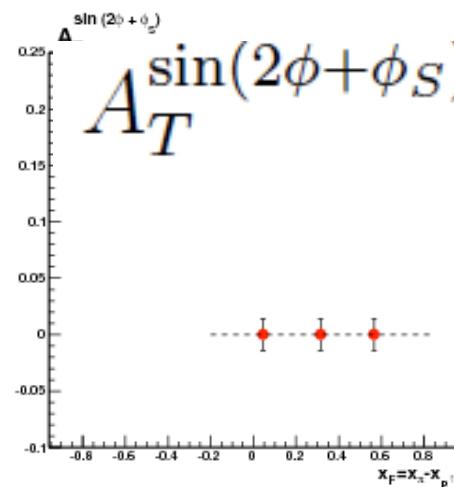
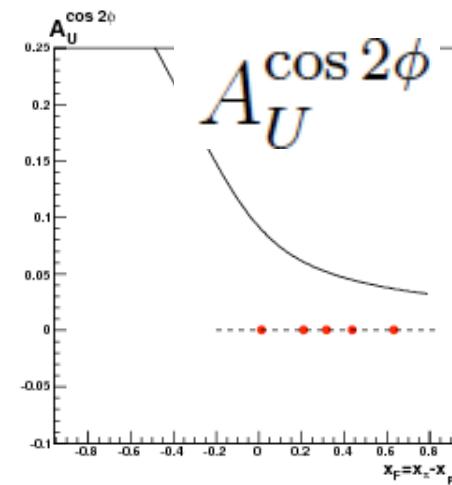
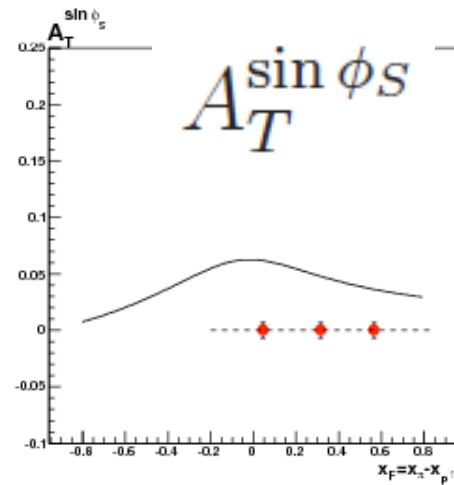
(HMR): $4. \leq M_{\mu\mu} \leq 9.$ GeV/c²

(IMR): $2.0 \leq M_{\mu\mu} \leq 2.5$ GeV/c²



DY@COMPASS projections III

J/ ψ region: $2.9 \leq M_{\mu\mu} \leq 3.2$ GeV/c²

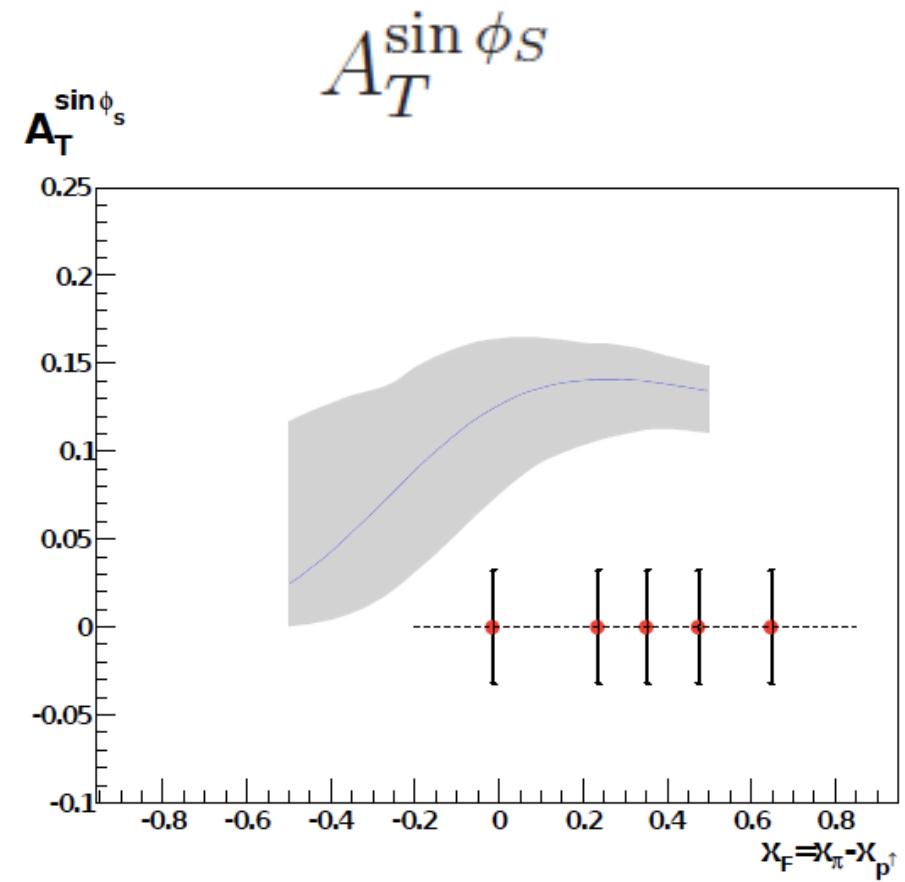
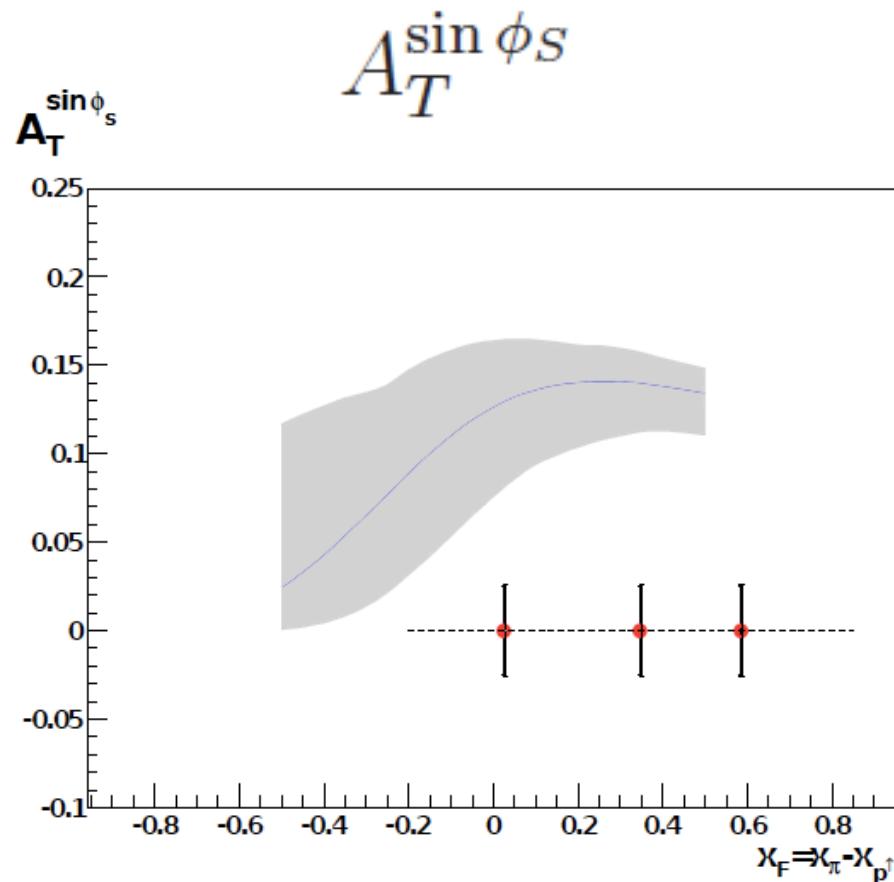




DY@COMPASS projections IV



(HMR): $4. \leq M_{\mu\mu} \leq 9. \text{ GeV}/c^2$





DY@COMPASS - set-up

$$\pi^- p \rightarrow \mu^- \mu^+ X$$


The main characteristics of the future Drell-Yan experiment:

1. Small cross section → High intensity hadron beam (up to 10^9 pions per spill) on the COMPASS PT
2. High intensity hadron beam on thick target →
 1. Hadron absorber to stop secondary particles flux
 2. Beam plug to stop the non interacted beam
 3. Radioprotection shielding around to protect things and people
 4. High-rate-capable radiation hard beam telescope
3. Hadron absorber + shielding → PT has to be moved by 2.2 meters upstream
4. LAS dominates in the acceptance → The performance of the LAS tracking system must be improved and muon trigger in LAS has to be well tuned.
5. Hadron absorber → vertex detector is very welcome to improve cell-to-cell separation

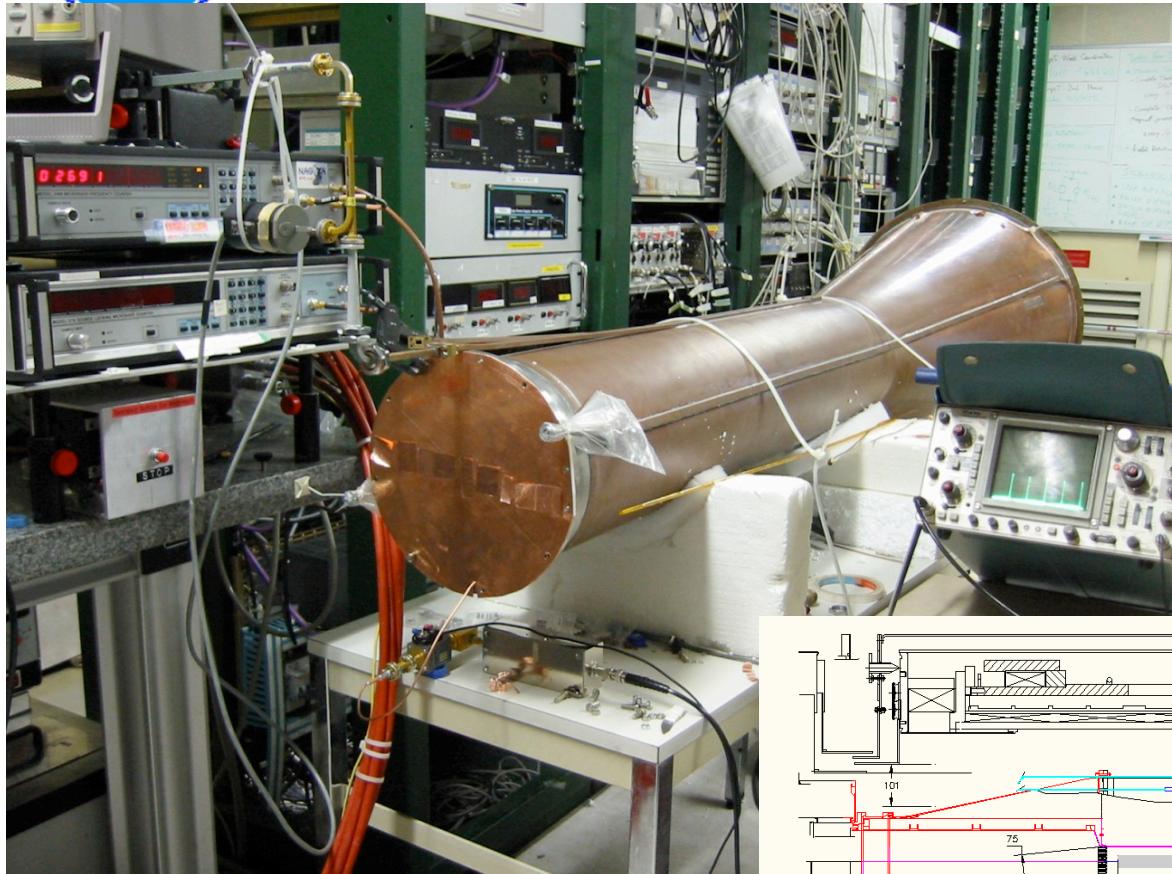


COMPASS-II DY list of upgrades

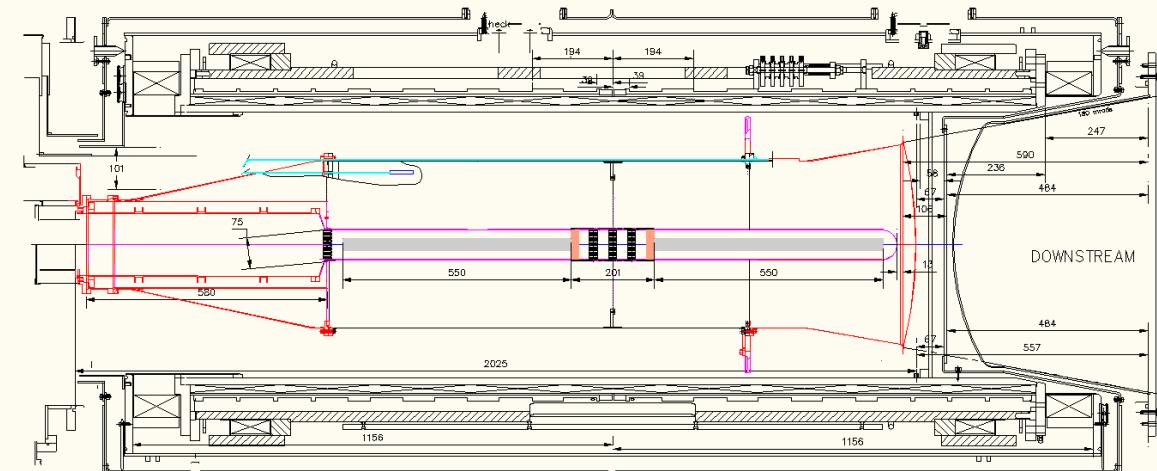
- COMPASS Polarised target:
 - New target holder (2x55 cm, 20 cm gap)
 - Old/modified Micro-Wave cavity (2 cells target)
 - PT Pump system refurbishing
- COMPASS PT has to be moved by ~2.2 meters upstream in order to release a space for the Hadron Absorber
- Hadron absorber (Alumina Al_2O_3) and beam plug (tungsten)
- Radio-Protection screen (stainless steel & borated polyeth.)
- New SciFi-based beam telescope
- H1 trigger hodoscope modification (central hole size adjustment)
- New vertex detector (SciFi based)
- New Large Area tracking station in the LAS
- Additional trigger hodoscope?



Polarised Target (mw cavity)



1. Modified standard OD cavity (3 cells)
 2. Use old SMC 2 cell cavity (needs new support system in OD magnet)



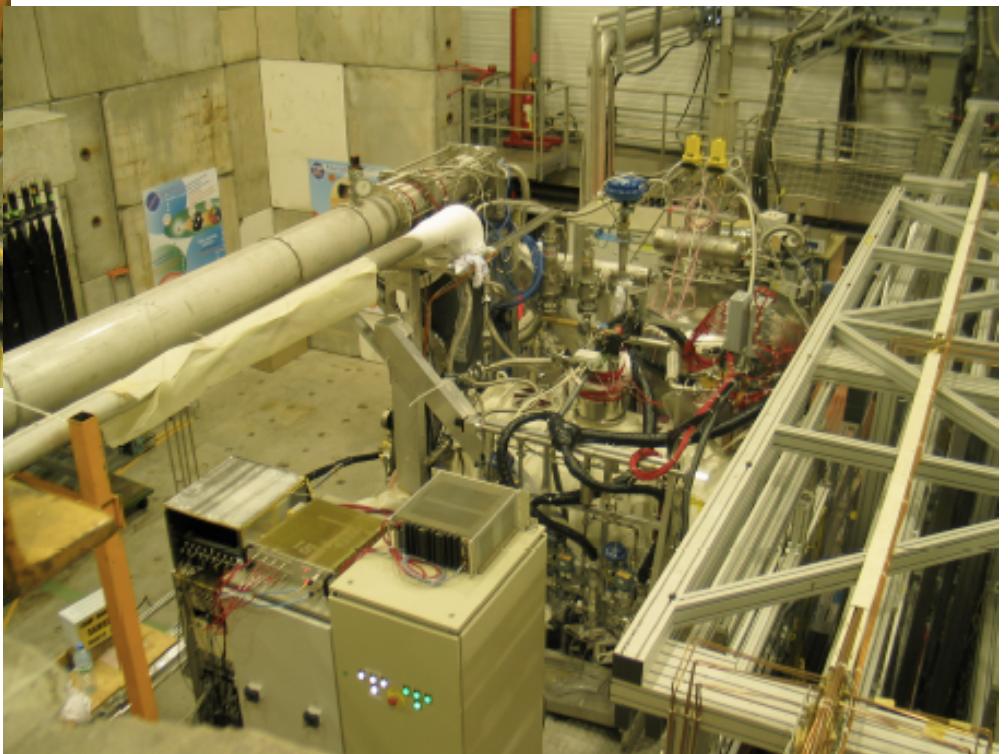
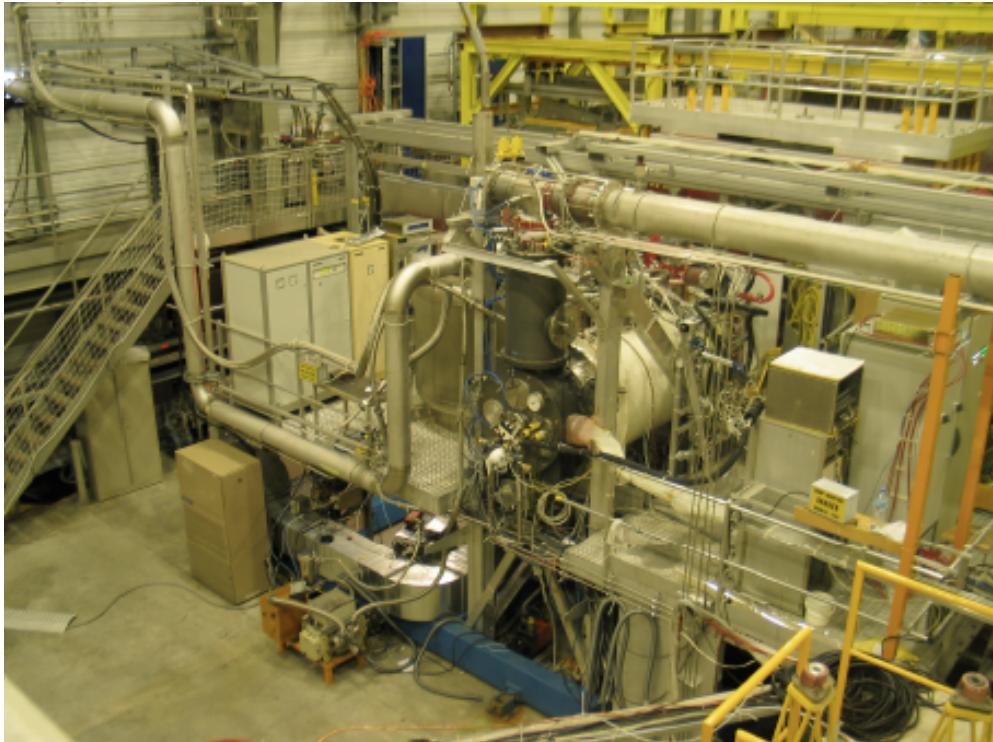
12-05-2011

Oleg Denisov

30



PT movement



12-05-2011

Oleg Denisov

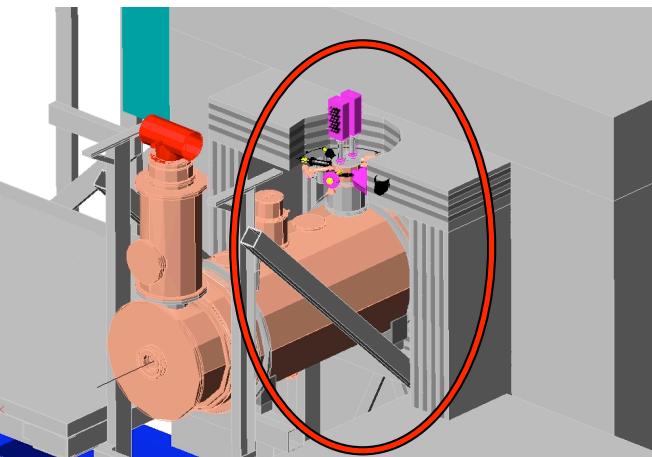
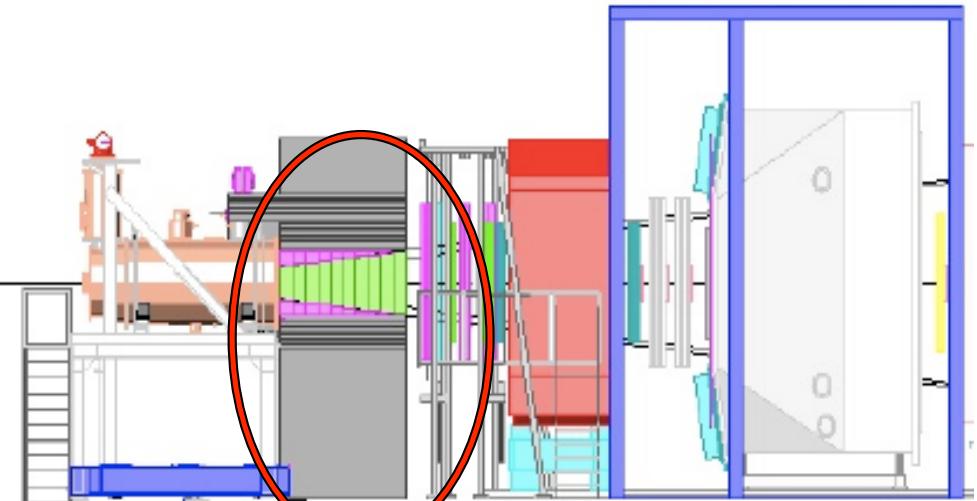
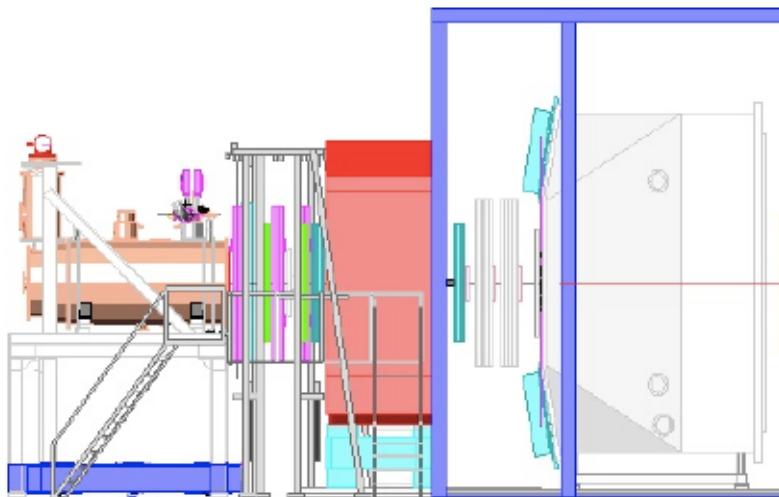
31



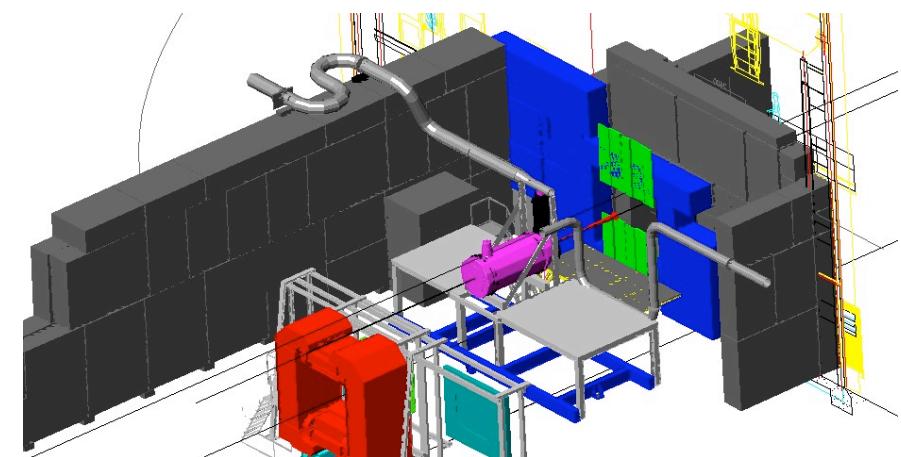
PT movement



Second step is the Drell-Yan set-up drawings production → will be done by the beginning of May



12-05-2011

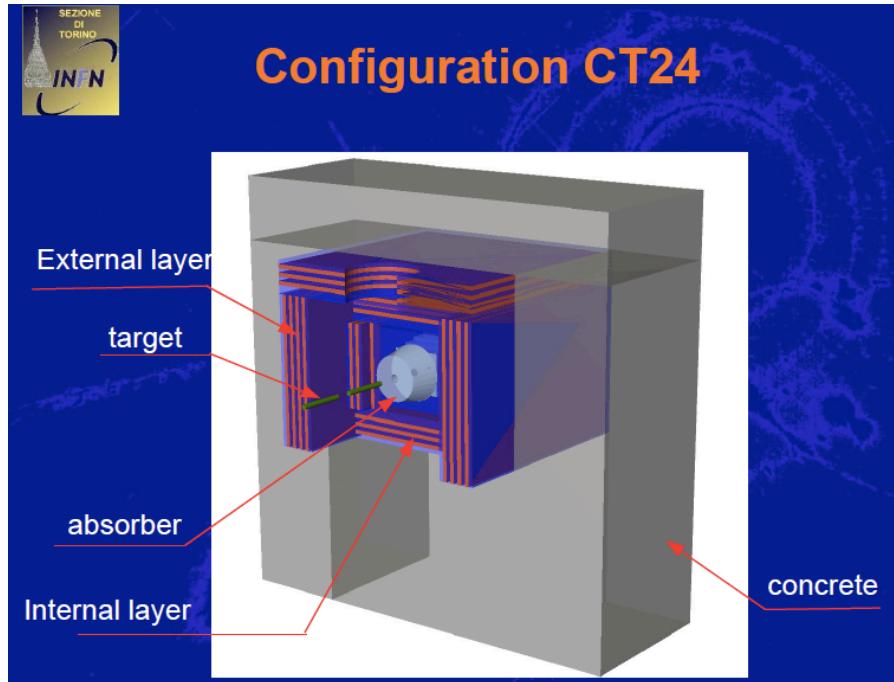


Oleg Denisov

32



Hadron absorber & beam plug

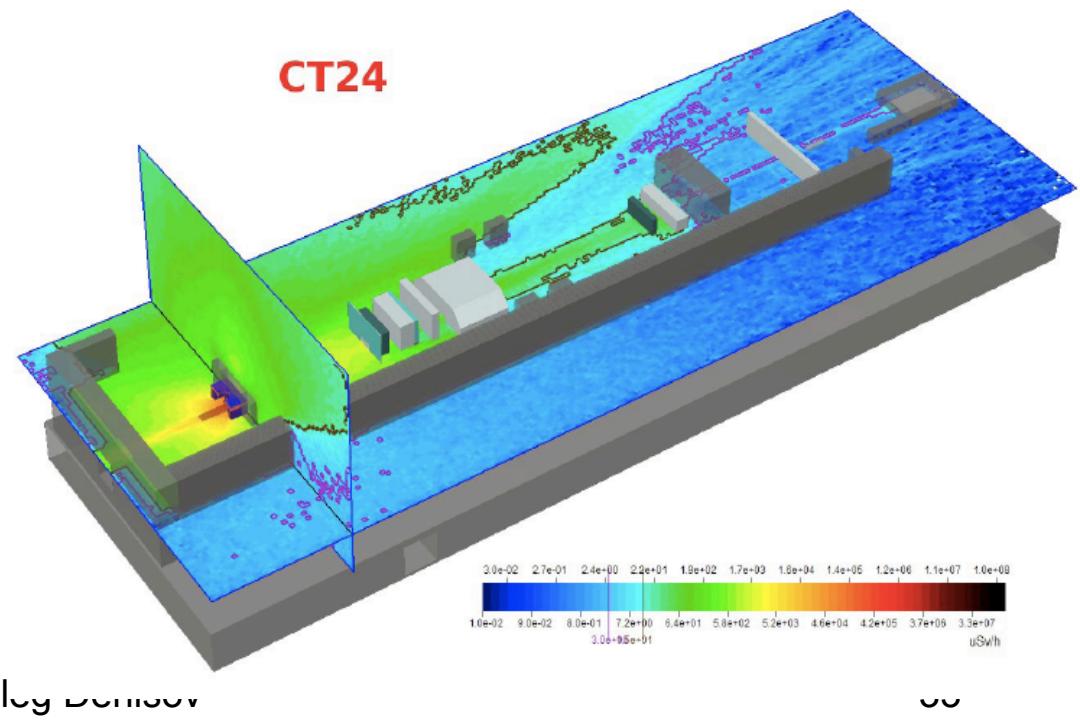


RP issue – approved by CERN RP
for the maximal possible beam
intensity 10^9 pions per spill and
super cycle duration 33,6 s, flat
top 10 s.

12-05-2011

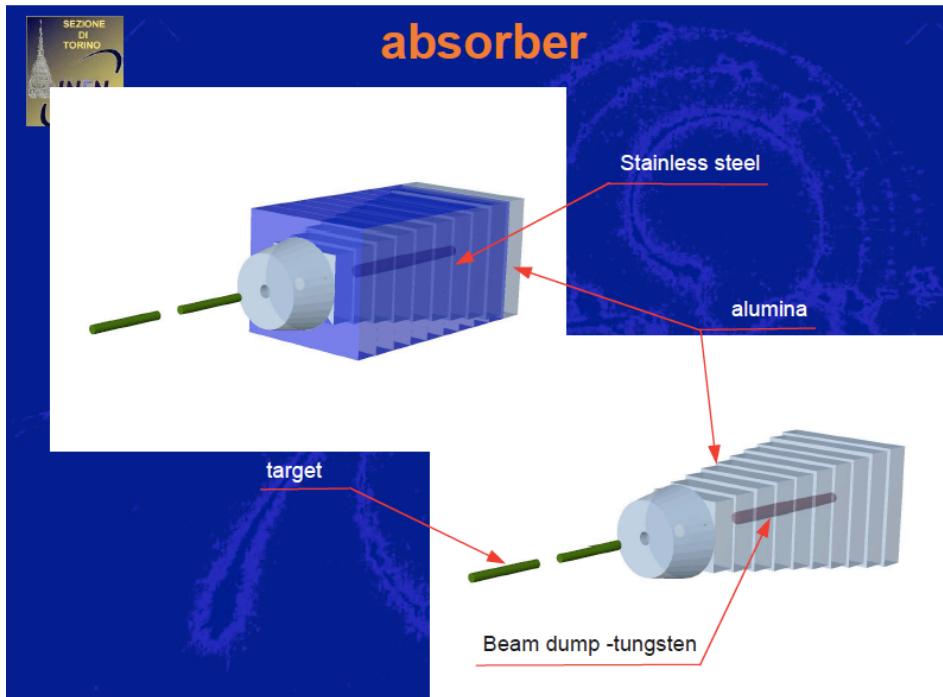
Purpose:

1. To stop the non-interacted beam
2. To spot secondary hadron flux to avoid spectrometer illumination
3. To protect people and things from the irradiation
4. Very COMPACT and TRANSPARENT



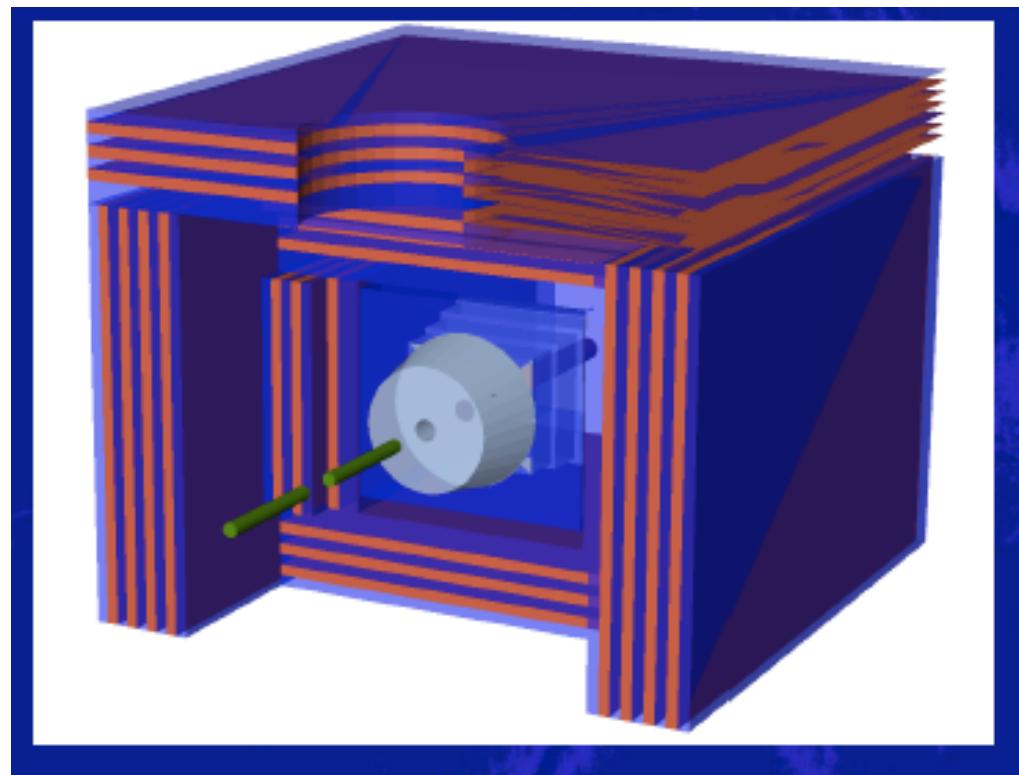


Hadron absorber & beam plug



Al_2O_3 – ideal material, very good ratio X/λ

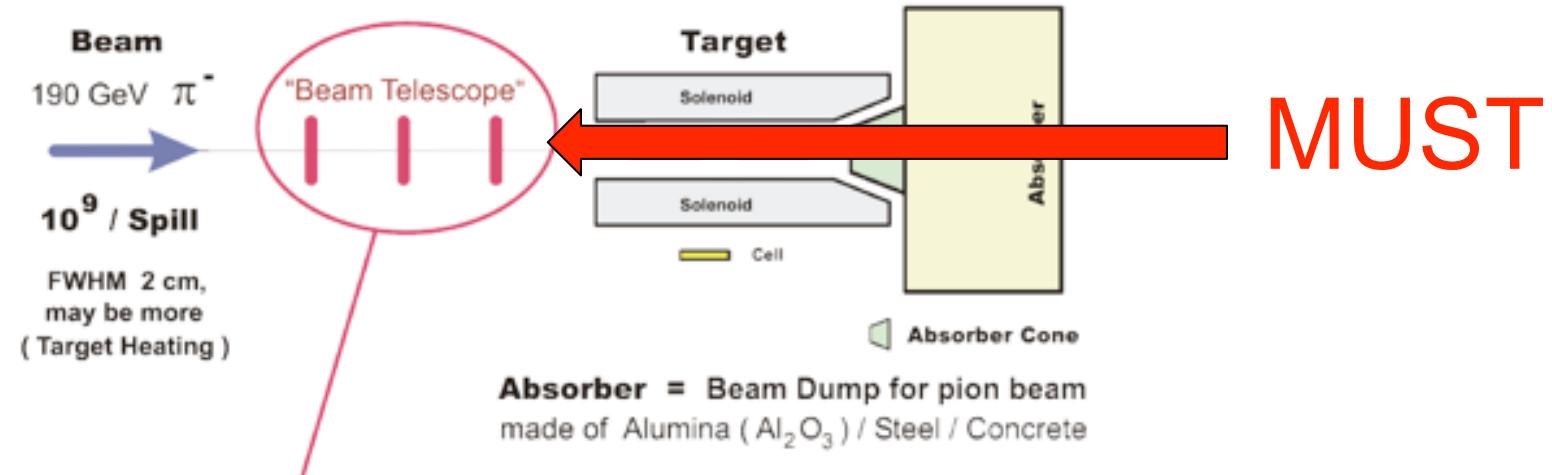
	X_0 [g/cm ²]	ρ [g/cm ³]	$\lambda_{int}(\pi)$ [g/cm ²]
Concrete	26,60	2,30	128,6
Alumina	27,94	3,97	129,3
Stainless Steel	13,94	7,90	160,9
Carbon	42,7	2,27	117,8



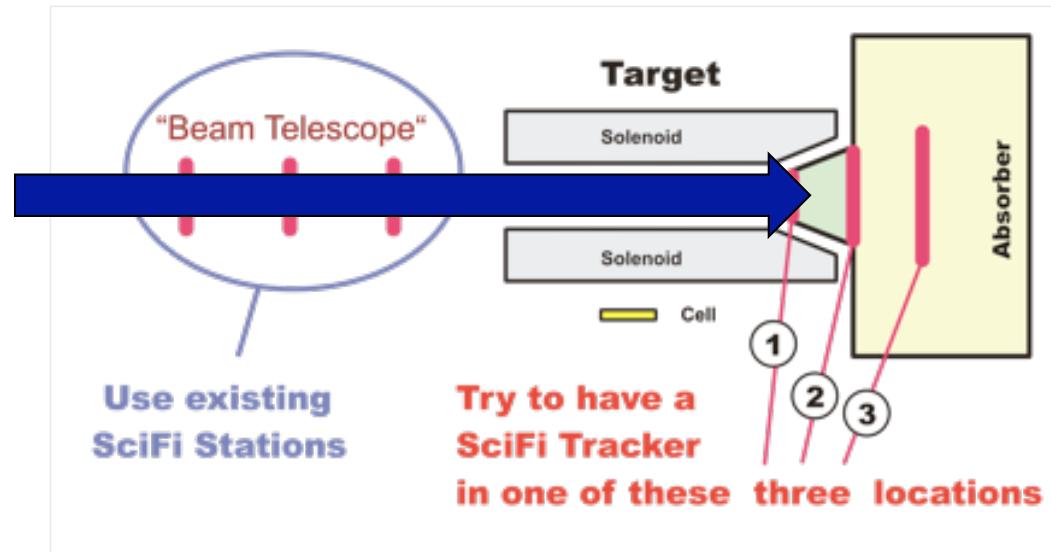
Must be compatible with the PT platform and the access to the PT instrumentation has to be provided



NEW SciFi telescope & vertex detector



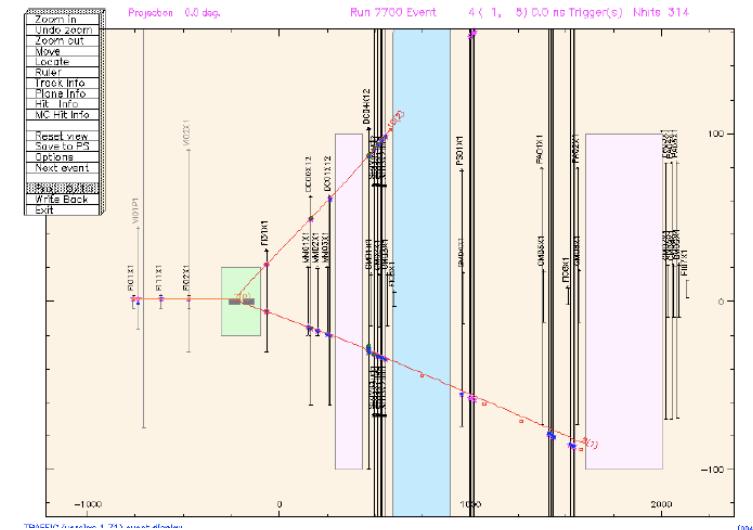
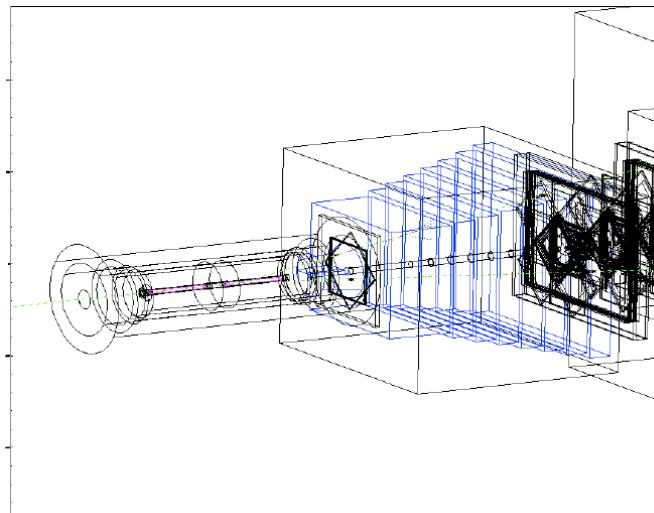
Very important





NEW Sci-Fi telescope & vertex detector

Very important but we can start without



Geometry	$\sigma_{\Delta M}$ (MeV/c ²)	$\sigma_{\Delta V_z}$ (cm)	$\sigma_{\Delta V_x}$ (cm)	$\sigma_{\Delta \phi}$ (mrad)	in target (z)	in target (z & r)
Solo Al ₂ O ₃	172	6.3	0.09	64	89.0%	73.6%
Telescopio fascio	174	6.2	0.1	57	89.3%	74.3%
Vtx det 10 cm	142	3.2	0.08	52	92.6%	78.3%
Vtx det 15 cm	134	2.2	0.08	51	93.8%	79.7%
Vtx det 20 cm	132	2.0	0.08	50	94.6%	80.6%
Vtx det 60 cm	128	1.8	0.07	50	95.8%	82.2%

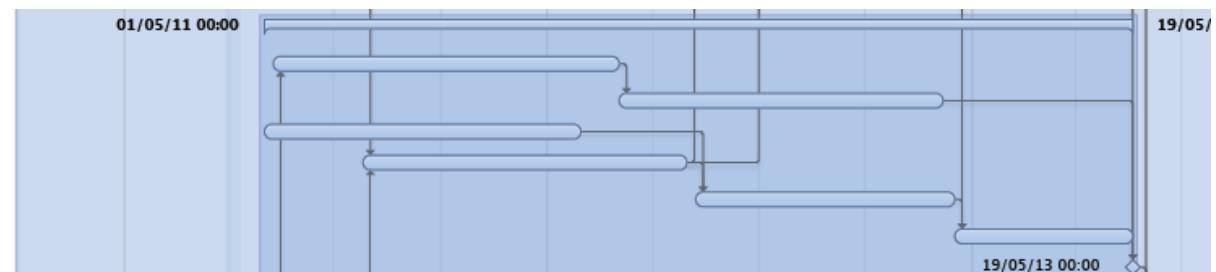
15) Beam telescope (SciFi's)

- 16) Design of the mechanical structure for beam telescope
- 17) Production of new detectors for the beam telescope
- 18) Feasibility study Vertex detector
- 19) Conceptual design HA+Vertex detector
- 20) Design of the mechanics for the vertex detector
- 21) Production of the new stations and design of the support
- ◆ 22) Test assembly with absorber

107s 01/05/11
00:00

42s 4g 1h 08/05/11 00:00
40s 01/03/12 00:00
39s 1h 01/05/11 00:00
40s 24/07/11 00:00
32s 1h 06/05/12 00:00
21s 6g 16/12/12 00:00
23h 19/05/13 00:00

01/05/11 00:00

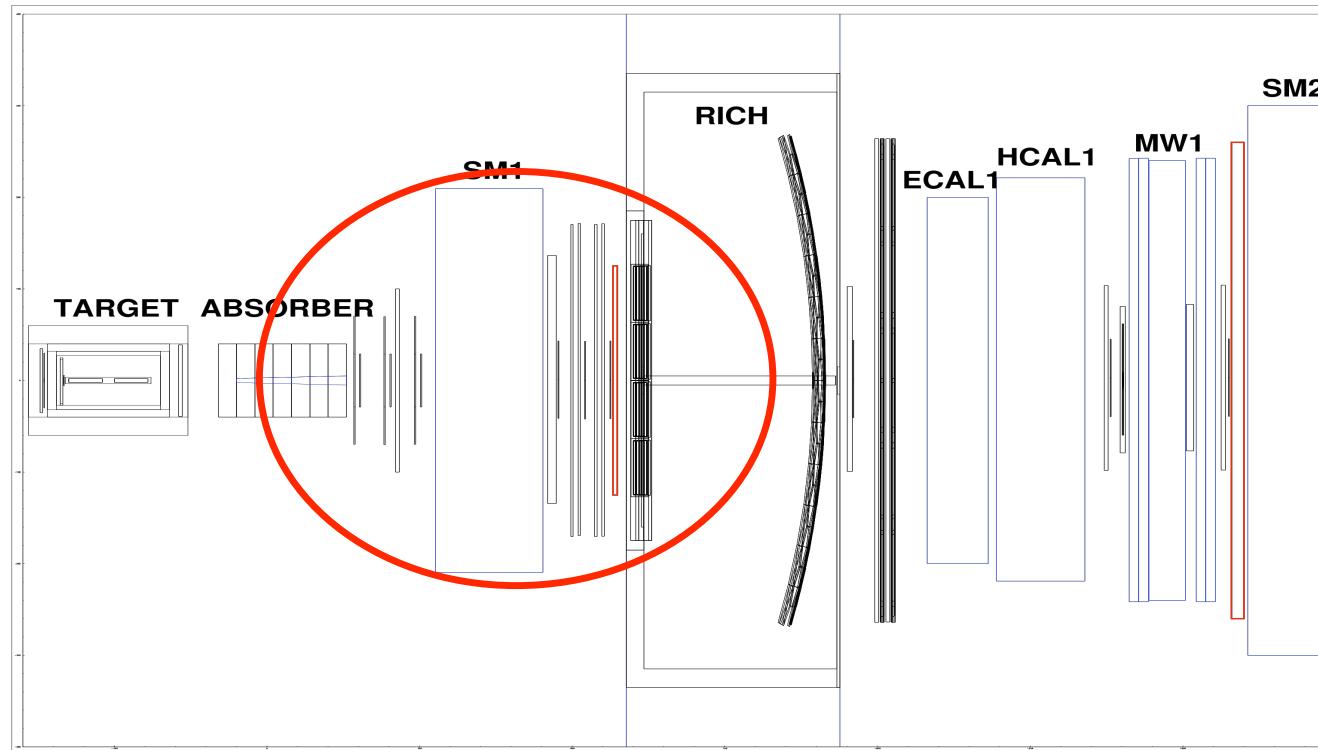




Tracking Station in LAS

Drell-Yan muon pairs at COMPASS kinematics:

1. 60% both muons stays in LAS
2. 36% 1 muon in LAS and another in SAS



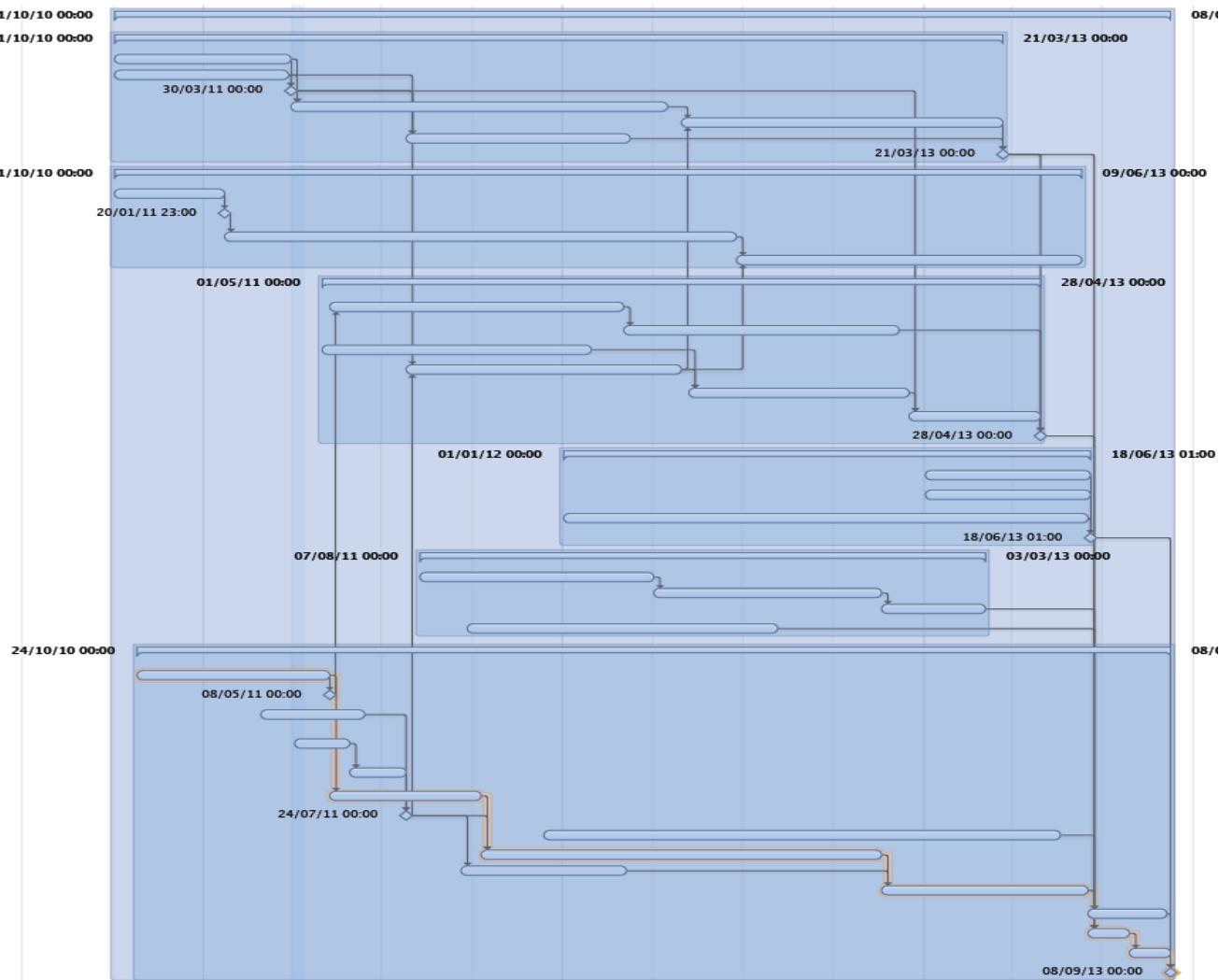


COMPASS-II DY preparation timelines: no show stopper



08/09/2013 – Drell-Yan experiment is ready for beam

- | | | |
|---|-----------|----------------|
| • 1) Drell-Yan program upgrades | 153s 2g | 01/10/10 |
| • 2) Hadron absorber (HA) | 128s 6g | 01/10/10 |
| • 3) Hadron absorber MC study | 1h | 00:00 |
| • 4) Hadron absorber RP optimization | 25s 5g | 01/10/10 00:00 |
| ◆ 5) Concept design of the absorber | 25s 2g | 01/10/10 00:00 |
| • 6) Design of the absorber | 54s 4g | 30/03/11 00:00 |
| • 7) Absorber production | 46s 4g 1h | 29/04/12 00:00 |
| • 8) HA support structure design | 32s 4g 1h | 24/07/11 00:00 |
| ◆ 9) Test assembling HA+support | | 21/03/13 00:00 |
| • 10) Radioprotection shieldings | 140s 2g | 01/10/10 |
| • 11) Monte Carlo optimisation | 16s | 01/10/10 00:00 |
| ◆ 12) Decision on the concept of the shielding | | 20/01/11 23:00 |
| • 13) R/P shielding design + support structure design | 74s 2g | 20/01/11 23:00 |
| • 14) R/P shielding + support production | 50s | 24/06/12 00:00 |
| • 15) Beam telescope (SciFi's) | 104s | 01/05/11 |
| • 16) Design of the mechanical structure for beam telescope | 42s 4g 1h | 00:00 |
| • 17) Production of new detectors for the beam telescope | 40s | 01/03/12 00:00 |
| • 18) Feasibility study Vertex detector | 39s 1h | 01/05/11 00:00 |
| • 19) Conceptual design HA+Vertex detector | 40s | 24/07/11 00:00 |
| • 20) Design of the mechanics for the vertex detector | 32s 1h | 06/05/12 00:00 |
| • 21) Production of the new stations and design of the support | 18s 6g | 16/12/12 00:00 |
| ◆ 22) Test assembly with absorber | 23h | 28/04/13 00:00 |
| • 23) Trigger system modification | 76s 2g | 01/01/12 |
| • 24) H1 modification (central hole) | 24s | 01/01/13 00:00 |
| • 25) Trigger configuration/logic modification | 24s | 01/01/13 00:00 |
| • 26) ??? Additional trigger hodoscope (extentions to the existing)?? | 75s 6g | 01/01/12 00:00 |
| ◆ 27) Trigger system ready | 23h | 18/06/13 01:00 |
| • 28) Polarised Target modification | 82s 1h | 07/08/11 |
| • 29) Microwave cavity design | 34s | 07/08/11 00:00 |
| • 30) Microwave cavity construction | 33s 1h | 01/04/12 00:00 |
| • 31) Microwave cavity test | 15s | 18/11/12 00:00 |
| • 32) Target holder design and construction | 45s | 25/09/11 00:00 |
| • 33) Target region modification | 150s | 24/10/10 |
| • 34) Lay-out of the DY experiment (upstream part) | 28s | 00:00 |
| ◆ 35) Preliminary lay-out fixed | | 08/05/11 00:00 |
| • 36) Access to the are (doors etc.) – discussion with CERN (Lau) | 14s 6g | 27/02/11 00:00 |
| • 37) Study of the radiation influence on the sensitive elements PT + electronics | 23h | 08/04/11 00:00 |
| • 38) Optimisation of the sensitive element positioning in the area | 8s | 29/05/11 00:00 |
| • 39) Plan for the PT infrastructure modification (piping etc.) | 22s | 08/05/11 00:00 |
| ◆ 40) Final DY lay-out | | 24/07/11 00:00 |
| • 41) PT pump system refurbishing | 74s 6g | 11/12/11 00:00 |
| • 42) PT infrastructure modification | 23h | |
| • 43) PT platform modification | 58s 1h | 09/10/11 00:00 |
| • 44) PT movement + infrastructure assembling | 24s | 18/09/11 00:00 |
| • 45) PT cooling down and test polarisation | 29s 6g | 18/11/12 00:00 |
| • 46) HA installation | 23h | |
| • 47) Radioprotection shielding installation | 11s 2g | 16/06/13 00:00 |
| ◆ 48) Ready for data taking | 22h | 16/06/13 00:00 |
| | 6s | 28/07/13 00:00 |
| | 6s | 08/09/13 00:00 |





COMPASS Running until 2016 III



Decision by the Collaboration (F.K. slide):

2014-2016

Tentative schedule

2012	Primakoff	18 weeks
	GPDs	6 weeks
2014	Drell-Yan	
2015	GPDs	
2016	GPDs	



End of 2013 – short DY
test very desirable

2013 Long shut down necessary for PT mouvement and installation

→ Agreed upon



COMPASS: Summary



- Pion and, later probably antiproton beams (50-200 GeV)
- Drell-Yan process dominated by the contribution from the valence quarks (both beam and target), $\tau = x_1 x_2 = Q^2/s \approx 0.05 \div 0.3$
- Solid state polarised targets, NH_3 and ${}^6\text{LD}$, in case of hydrogen target
- Statistical error on single spin asymmetries after one year of running is on the level 1÷2%
- The proposal was recommended by SPSC for approval on September 29th. The initial recommendation is for 3 years (likely 2013-2015). The SPSC also proposes a schedule of two years GPD and one year DY.
- Proposal is approved by the CERN Research Board on December 1st 2010.
- During the last Collaboration meeting the decision is taken by the Collaboration to run first Drell-Yan experiment (2013 → 2014) and then DVCS program.
- Looking at the huge activity in the field a lot of new DY data is just behind the corner



- Spares



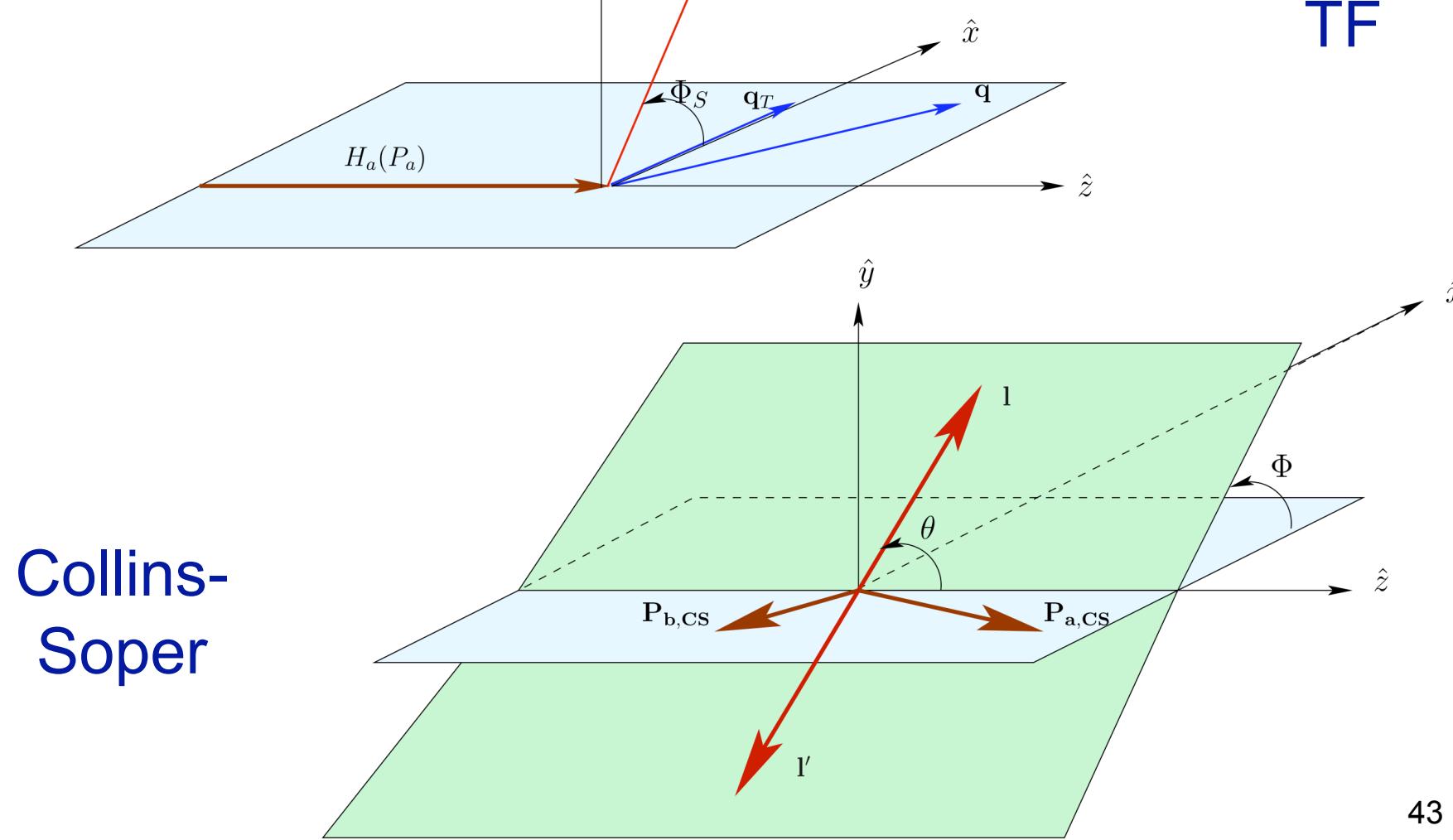
TMDs at Drell-Yan: road map



- 2010 – COMPASS polarised SIDIS data (Sivers, transversity via global data fit)
- 2010 – 2013? E906 (SeaQuest) – pp Drell-Yan – Boer-Mulders of the proton
- 2013 - 2016 COMPASS polarised Drell-Yan pi-p data – TMDs universality and T-odd TMDs sign change SIDIS \leftrightarrow DY (for Boer-Mulders function study the input from E906 as well as new transversity fit from the global data analysis is very welcome)
- 2015 → RHIC, NICA pp (un)polarised DY data – very welcome – complimentary to COMPASS
- 2017 → more COMPASS data, antiprotons?.....
- **MANY NEW data - just behind the corner**



Coordinate systems



Collins-
Soper



Drell-Yan Workshop at CERN, April 26-27



Studying the hadron structure in Drell-Yan reactions

26-27 April 2010 CERN

Overview

[Programme](#)

[Registration](#)

[Registration Form](#)

[List of registrants](#)

Laptop and Wireless
access

[Access Cards](#)

[Accomodation](#)

[How to get to CERN](#)

[Support](#)

Since a long time the Drell-Yan (DY) process is considered to be a powerful tool to study hadron structure. In the past, several experiments were successfully carried out using unpolarised beams and targets. Nowadays, taking into account the much advanced understanding of the spin structure of the nucleon, we are discussing a new generation of DY measurements using polarised beams and/or targets.

The COMPASS collaboration is currently preparing a proposal for future studies of nucleon structure beyond 2011. One of the main aims is a first measurement of transverse-momentum-dependent parton distributions (TMDs) using the Drell-Yan process on a transversely polarised proton target hit by a pion beam. Among the distributions to be studied are Sivers, Boer-Mulders and pretzelosity TMDs as well as transversely polarised quark distributions.

The workshop will review ongoing theoretical and experimental efforts related to the Drell-Yan process. Detailed presentations and discussions of the theoretical aspects will be complemented by descriptions of planned fixed-target and collider experiments.

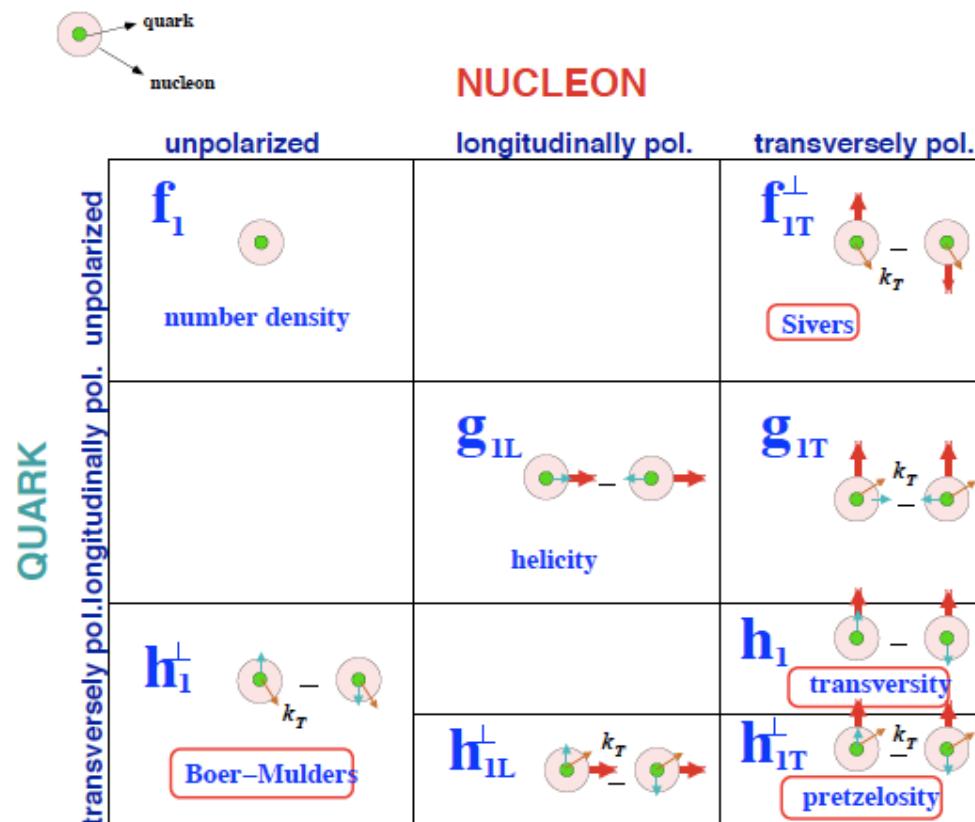
Organizers: Paula Bordalo (LIP-Lisbon and IST/UTL)
Oleg Denisov (CERN/INFN-Torino)
Eva-Maria Kabuss (Mainz)
Fabienne Kunne (CEA Saclay)
Alain Magnon (CEA Saclay)
Gerhard Mallot (CERN)
Anna Martin (Univ. Trieste and INFN-Trieste)
Wolf-Dieter Nowak (CERN)
Daniele Panzieri (Univ. Alessandria and INFN-Torino)

Dates: from 26 April 2010 09:00 to 27 April 2010 18:00

Location: CERN
Salle Andersson
Room: 40-S2-A01

Parton distribution functions

Taking into account the intrinsic transverse momentum k_T of quarks, at LO 8 PDFs are needed for a full description of the nucleon:





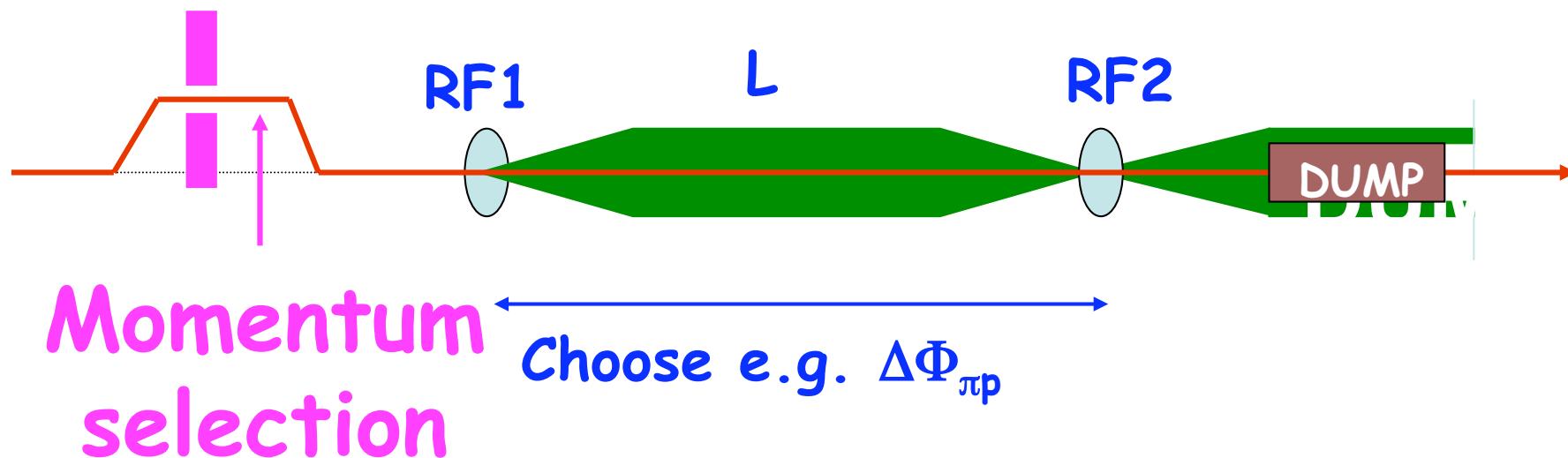
WHAT ABOUT A RF SEPARATED \bar{p} BEAM ???



First and very preliminary thoughts, guided by

- recent studies for P326
- CKM studies by J.Doornbos/TRIUMF, e.g.
<http://trshare.triumf.ca/~trjd/rfbeam.ps.gz>

E.g. a system with two cavities:



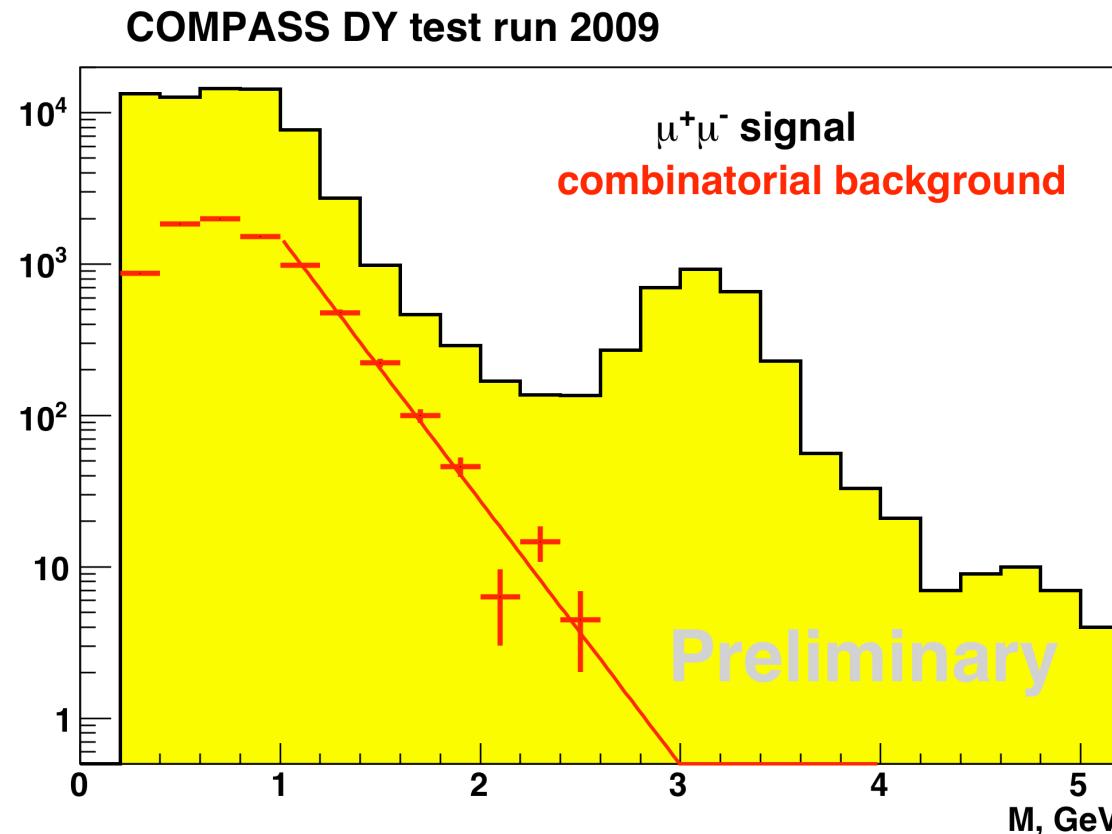
$$\Delta\Phi = 2\pi (L f / c) (\beta_1^{-1} - \beta_2^{-1}) \text{ with } \beta_1^{-1} - \beta_2^{-1} = (m_1^2 - m_2^2) / 2p^2$$



DY@COMPASS - feasibility – Background II – Combinatorial



- 2009 beam test id very important
- Combinatorial background suppressed by ~ 10 at 2.0 GeV/c dimuon invariant mass (beam intensity ~ 8 times lower wrt Proposal)

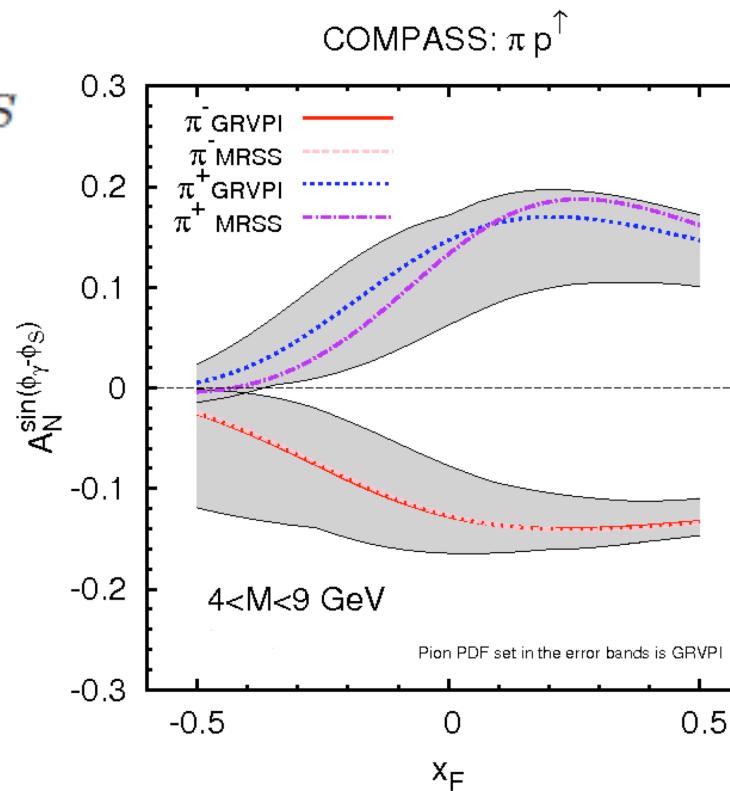




DY@COMPASS uncertainty coming from the pion PDFs



$A_T^{\sin \phi_S}$



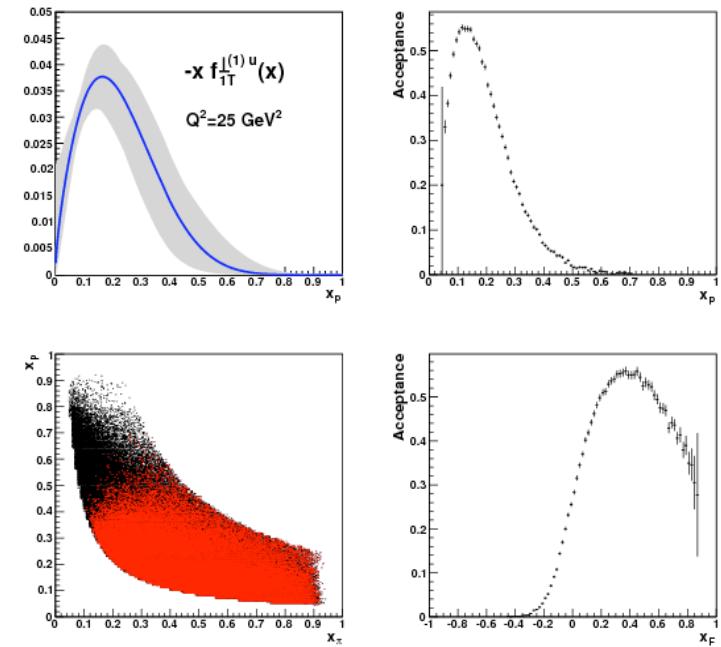
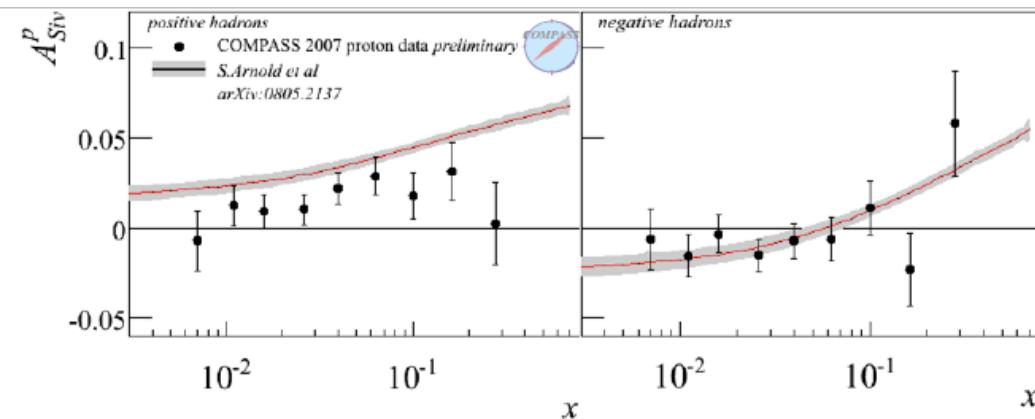
In case of $\pi^- p$ scattering the valence pion \bar{u} unpolarised PDF is well known and there is no difference between two pdf sets. In case of $\pi^+ p$ scattering there is a little contamination coming from sea \bar{u} of the pion, which annihilates with valence u quark of the proton, because the distribution functions are weighted in the cross section with e_q^2 , and the $\bar{u}u$ contribution is multiplied by factor 4/9 while the $\bar{d}d$ by factor 1/9. Thus, the contribution from the sea \bar{u} of the pion can not be neglected, it is less known with respect to valence PDFs and it explains the difference from one data set (GRVPI) to another (MRSS).



DY@COMPASS → SIDIS complementarity



- TMD PDFs study in SIDIS is an important part of the COMPASS-I program
- COMPASS-II, TMDs study in Drell-Yan processes:
 - We change the probe (elementary process)
 - We upgrade the spectrometer and we change its lay-out
 - We change the kinematic range





Some indications for the future Drell-Yan experiments



$$\delta A = \frac{1}{P_b f} \frac{1}{\sqrt{N_{sig}}} \sqrt{1 + \frac{N_{sig}}{N_{backg}}}$$

$$\tau = x_a x_b = M^2/s$$

1. Drell-Yan experiments:

- High luminosity (DY Cross Section is a fractions of nanobarns) and large angular acceptance, better pion or antiproton beams (valence anti-quark)
- Sufficiently high energy to access ‘safe’ of background free $M_{||}$ range ($4 \text{ GeV}/c < M_{||} < 9 \text{ GeV}/c$)
- Good acceptance in the valence quark range $x_B > 0.05$ and kinematic range: $\tau = x_A x_B = M^2/s > 0.1$

2. Polarised Drell-Yan:

- Good factor of merit (F_m), which can be represented as a product of the luminosity and beam (target) polarisation (dilution factor) ($F_m \sim L \times P_{beam} (f)$)